

NASA SeaWinds Scatterometer

SeaWinds Science Data Product

User's Manual

Overview & Geophysical Data Products



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Jet Propulsion Laboratory
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Editor: Ted Lungu

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1 Introduction

The purpose of the SeaWinds Science Data Product User's Manual is to provide assistance to investigators so they can make effective use of the SeaWinds on ADEOS-II Science Data Products, which are produced by the NASA Scatterometer Projects and distributed by the NASA Physical Oceanography Distributed Active Archive Center (PO.DAAC) at the Jet Propulsion Laboratory. This User's Manual provides investigators a comprehensive description of the content and format of the data products and gives examples of data usage. In addition, it discusses the SeaWinds geophysical processing algorithms and how they relate to the data products. An overview of the ADEOS-II mission and an introduction to the operation of the instrument and ground data systems are provided for new investigators. The algorithm and data descriptions presented in this User's Manual cover the σ_o and geophysical data products (Levels 1B, 2A, 2B and 3).

1.1 How to Use this Document

For experienced users of scatterometry data, the key parts of this guide are Sections 3, 5, 6, 7 and 8. Section 3 should be reviewed as it introduces the design and operating characteristics of the SeaWinds scatterometer, including key engineering parameters required to understand the data. Section 5 provides a more in-depth summary of the data processing algorithms, with specific references to the data elements in the data products. Section 6 completely describes the contents and the format of the data products from Levels 1B to 3. Section 7 describes the Hierarchical Data Format (HDF) and other software conventions adhered to by these data products. Section 8 is a practical guide to the use of the SeaWinds science data, namely how to obtain the data and read the files.

The less experienced or newer users of scatterometer data should read all sections, including the introductory sections of this guide prior to using the data products. Section 2 gives an overview of the mission, including the science requirements and goals, a description of the ADEOS-II spacecraft, the SeaWinds scatterometer instrument on the satellite, and a brief description of the overall ADEOS-II ground system segment. Section 4 describes the SeaWinds Ground Data Processing system at JPL, and gives a high-level functional walkthrough of the data processing and quality assurance stages. Newer users will find the practical guide given in Section 8 of particular help in analyzing SeaWinds data.

Ancillary information, of potential interest to all users, is presented in Section 9. The group of appendices, which make up Section 9, covers definitions of commonly used terms, acronyms, and a list of scatterometry-related references and points of contact via various means. Selected data element definitions for levels 1B, 2A, 2B, and complete data definitions for level 3 are given in Appendix 9.6.

1.2 Conventions

1.2.1 Units

All quantities reported in the data products data are computed and expressed in MKS units. Distances are reported in meters, speeds in meters per second, and powers are in watts (or decibels relative to 1

watt). Ratio quantities including the radar backscatter (σ_0) are generally reported in decibels (dB), particularly when they cover a wide dynamic range of values.

Antenna azimuths are measured clockwise from the spacecraft-heading vector. Beam and cell azimuths and wind directions are in degrees measured clockwise from North. Longitudes are measured eastward from the Greenwich meridian and range from 0 to 359.99. Incidence angles are computed relative to the local normal to the Earth ellipsoid.

All time tags on data records are given in Coordinated Universal Time (UTC), in a standard ASCII CCSDS format (yyyy-dddThh:mm:ss.sss). Where times are also given in seconds (as in the Level 1B record), the reference epoch is 1 January 1993 at 00h00 UTC.

1.2.2 Resolution

Quoted resolutions for σ_0 measurements are defined as the dimension of the equivalent-area square footprint, which can be practically estimated as the square root of the cell area.

SeaWinds on ADEOS-II is capable of generating σ_0 measurements at a variety of resolutions, including the “spot” or “egg” footprint of the full beam, the “slice” footprint of individual range-resolution elements, and “composite” footprints made up of multiple slices falling in a wind vector cell. These different types of measurements and their derivation are described in Section 5.

The SeaWinds antenna footprint is an ellipse approximately 25-km in azimuth by 37-km in the look (or range) direction. Signal processing provides commandable variable range resolution of approximately 2- to 10-km.

The wind retrieval resolution is defined as the dimension of a wind vector cell in which σ_0 measurements have been grouped. For SeaWinds, the wind vector cell grid has a resolution cellsize of 25 km x 25 km, along- and cross-track.

1.2.3 Wind Direction Convention

The oceanographic, or flow vector, convention for wind direction is adopted for SeaWinds. Under this convention, a wind direction of θ implies a flow toward the north. This is in contrast to the meteorological, or “out of”, convention, for which a “north” wind (θ direction) flows from the north. Conversion between the two conventions is performed by simply reversing the directions (adding 180° modulo 360°).

1.2.4 Reference Height for Surface Winds

The adopted reference height for all wind vectors is 10 meters.

1.2.5 Data Flagging and Editing

The policy adopted within the processing algorithms and software design is to flag values that are out of range or to indicate a non-nominal condition. Except where otherwise noted, a “1” or “set” bit

indicates an error or abnormal condition, and a “0” or “cleared” bit indicates a normal condition. Some informational flags may have a number of set bits under normal conditions. As explained in the Software Interface Specification (SIS) documents, quality flag bits are set at the beginning of processing and are cleared when tests are performed and passed. If abnormal conditions terminate processing early, some bits may remain.

Please refer to Section 9.6 or to the SIS documents for the dependency tables.

1.3 Applicable Documents

1.3.1 Software Interface Specifications

Level 0 Data Software Interface Specification, Project Document 686-644-4, JPL D-16075, August 1998.

Level 1A Data Software Interface Specification, Project Document 686-644-5, Rev B, JPL D-20561, May 2001.

Level 1B Data Software Interface Specification, Project Document 686-644-1, Rev B, JPL D-20562, July 2002.

Level 2A Data Software Interface Specification, Project Document 686-644-2, Rev C, JPL D-20563, November 2001.

Level 2B Data Software Interface Specification, Project Document 686-644-3, Rev C, JPL D-20564, July 2002.

Level 3 Data Software Interface Specification, Project Document 686-644-23, JPL D-19147, April 2002.

Processing Tables Software Interface Specification, Project Document, 686-644-6 Rev A, JPL D-16080, July 2000.

1.3.2 Related Documents

SeaWinds Mission Requirements, M. H. Freilich (Science requirements)

Science Algorithm Specifications for SeaWinds, A. Zhang, R. S. Dunbar, S. V. Hsiao, K. Pak, JPL SeaWinds internal project document, JPL D-D21978, October 2001.

SeaWinds Experiment Implementation Plan, Volume III: Ground System Technical Management, October 1994, JPL D-8743, PD 686-010.

SeaWinds Experiment Functional Requirements, April 1998, JPL D-TBD, PD 686-210A.

SeaWinds Experiment Science and Mission Requirements, January 1995, JPL D-10965, PD 686-050.

SeaPAC System Functional Requirements, September 2000, JPL D-16073, PD 686-610 Rev A.

Planetary Science Data Dictionary Document, July 15, 1996, JPL D-7116, Rev. D, V6 MGSO0099-05-00.

Science Data Processing Segment (SDPS) Database Design Schema Specification for the ECS Project, EOSDIS Core System Project, Hughes Information Technology Systems, Upper Marlboro, Maryland, December, 1995, 311-CD-002-004.

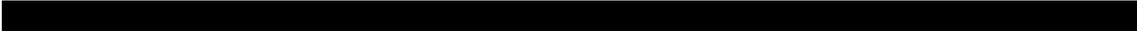
Getting Started with HDF, Version 3.2, National Center for Supercomputing Applications, University of Illinois at Urbana-Champaign, May, 1993.

HDF Reference Manual, Version 4.1r5, National Center for Supercomputing Applications, University of Illinois at Urbana-Champaign, November, 2001.

HDF User's Guide, Version 4.1r5, National Center for Supercomputing Applications, University of Illinois at Urbana-Champaign, November, 2001.

1.4 Change Control

This document is maintained by PO.DAAC and will be kept current to reflect changes in algorithms and data products content. Algorithm specifications and software changes are controlled by the SeaWinds Change Control Board (SWCCB).



2 ADEOS-II Mission Overview

2.1 Mission Description

The SeaWinds on ADEOS-II mission is a follow on to SeaWinds on QuikSCAT, which in turn was a “quick recovery” mission to fill the gap created by the loss of data from the NASA Scatterometer (NSCAT), when the ADEOS-1 satellite lost power in June 1997. QuikSCAT was launched from California’s Vandenberg Air Force Base aboard a Titan II vehicle on June 19, 1999. It continues to add to the important ocean wind data set begun by NSCAT in September 1996. SeaWinds launch in December 14, 2002, aboard Japan’s Advanced Earth Observing Satellite-II (ADEOS-II).

The SeaWinds instrument on the ADEOS-II satellite is a scatterometer that measures near-surface wind velocity over Earth’s oceans. These measurements will help to determine atmospheric forcing, ocean response and air-sea interaction mechanisms on various spatial and temporal scales. Operational users will seek to develop improved methods of assimilating wind data into numerical weather and wave-prediction models. Scatterometer wind data, combined with measurements from various scientific disciplines, will help to understand mechanisms of global climatic change and weather.

The first spaceborne scatterometer flew as part of the Skylab missions in 1973 and 1974, demonstrating that spaceborne scatterometers were indeed feasible. The Seasat-A Satellite Scatterometer (SASS) operated from June to October 1978 and proved that accurate wind velocity measurements could be made from space. The SASS cross section measurements have been used to significantly refine the empirical model relating backscatter to wind velocity, and the SASS data have been applied to a variety of oceanographic and meteorological studies. A single-swath scatterometer operating at C-band is presently flying on the European Space Agency’s Earth Remote Sensing (ERS-2) mission, continuing the (nearly 9-1/2) year time series of C-band wind scatterometer measurements begun with ERS-1, through January 2001. Attitude problems on the satellite have precluded operation of the scatterometer since that time.

NSCAT was launched on ADEOS-1 (Midori) in August 1996 and returned nearly 10 months of dual-swath, 25-km resolution Ku-band backscatter and wind data until the demise of the spacecraft in June 1997.

2.1.1 Mission Requirements

The temporal scales of important motions in the atmosphere and the ocean range from seconds to decades, and spatial scales range from meters to tens of thousands of kilometers. Given the wide range of geophysical studies requiring surface wind velocity data, construction of a unified, consistent, achievable set of requirements for a satellite instrument is difficult. Following the successful flight of the Seasat scatterometer (SASS) in 1978, NASA established the interdisciplinary Satellite Surface Stress Working Group to define the scientific requirements for the next NASA spaceborne scatterometer system. As understanding of both science issues and scatterometer capabilities grew during the 1980’s, the Working Group report evolved into specific mission requirements. In short, the system must measure winds between 3 and 30 m/s with an accuracy better than (the greater of) 2 m/s or 10% in speed and 20° in direction with a spatial resolution of 50 km; virtually the entire ocean

surface must be covered at least once every two days; geophysically useful products must be produced within days after data are acquired; and the instrument must be designed to acquire data for at least three years in order to allow investigation of annual and interannual variability.

Table 2.1 SeaWinds Technical Mission Requirements

Quantity	Requirement	Applicable Range
Wind speed	2 m/s (rms)	3-20 m/s
	10%	20-30 m/s
Wind direction	20° (rms) selected ambiguity	3-30 m/s
Spatial resolution	25 km	σ_0 cells
	25 km	Wind vector cells
Location accuracy	25 km (rms)	Absolute
	10 km (rms)	Relative
Coverage	90% of ice-free ocean every day	
Mission duration	36 months	

2.2 Satellite Description

ADEOS-II consists of a mission module that carries mission instruments (observation sensors and other equipment) and a bus module that carries bus subsystems.

The observation sensors are:

- AMSR: NASDA's Advanced Microwave Scanning Radiometer measures physical parameters concerning water (e.g. water vapor, precipitation, sea surface temperature, sea surface wind, sea ice) by receiving weak microwave radiation from the Earth's surface and atmosphere.
- GLI: NASDA's Global Imager, an optical sensor, observes solar radiation reflected from the Earth's surface and measures physical content such as surface temperature, vegetation distribution, and ice distribution.
- ILAS-II: Environment Agency of Japan's Improved Limb Atmospheric Spectrometer-II measures the high-latitude stratospheric ozone layer, i.e. the vertical profiles of ozone, aerosols, chlorofluorocarbons, methane, nitrous oxide, and chlorine nitrate.
- POLDER: CNES's Polarization and Directionality of the Earth's Reflectances measures the polarization, directional, and spectral characteristics of the solar light reflected by aerosols, clouds, oceans, and land surfaces.
- NASA/JPL's SeaWinds scatterometer provides high accuracy sea surface wind speed and direction measurements by observing microwave reflection from the sea surface.

The other instruments are spacecraft equipment:

- DCS: the Data Collection System collects ground truth data from Data Collection Platforms located over the ocean.
- TEDA: the Technical Engineering Data Acquisition Equipment monitors the space environment and acquires engineering data related to the degradation, radiation damage, and anomalies of parts and materials.
- ODR: the Optical Disk Data Recorder, a magneto-optical disk, records and reproduces large volumes of data at high data rates.
- VMS: the Visual Monitoring System, a CCD camera, monitors and verifies deployment and other routine actions of ADEOS-II.
- DMS: the Dynamics Monitoring System, an experimental system consisting of accelerometers and a star tracker, monitors the dynamic behavior of ADEOS-II.

NASDA will launch the ADEOS-II satellite on an HIIA rocket from the Tanegashima Space

Center in Japan.

2.2.1 Nominal Orbital Parameters

The nominal orbit for ADEOS-II is defined by the following parameters:

Table 2.2 Nominal Orbital Parameters

Altitude	802.9 km
Descending (local) time	10:30 a.m.
Period	101.05 minutes
RECURRENT CYCLE	4 days, 57 revs
Paths/day	14¼
a (semi-major axis)	7189.2897 km
E (ECCENTRICITY)	0.001
i (inclination)	98.62°
Ω (right ascension of ascending node)	108.26°
ω (argument of perigee)	90.0°
M (mean anomaly)	270.1°

3 SeaWinds Sensor Overview

Satellite scatterometers are microwave radar instruments designed specifically to measure near-surface wind velocity (both speed and direction) over the global oceans under most all weather conditions. Wind stress is the single largest source of momentum to the upper ocean, driving oceanic motions on scales ranging from surface waves to basin-wide current systems. Winds over the ocean modulate air-sea fluxes of heat, moisture, gases and particulates, regulating the crucial coupling between atmosphere and ocean that establishes and maintains global and regional climate. Measurements of surface wind velocity can be assimilated into regional and global numerical weather models, improving our ability to predict future weather. As the only remote sensing systems able to provide accurate, frequent, high-resolution measurements of ocean surface wind speed and direction under both clear sky and cloudy conditions, scatterometers will play an increasingly important role in oceanographic, meteorological and climatic studies during the 1990s and beyond.

Scatterometers use an indirect technique to measure wind velocity over the ocean, since the atmospheric motions themselves do not substantially affect the radiation emitted and received by the radar. These instruments transmit microwave pulses and receive backscattered power from the ocean surface. Changes in wind velocity cause changes in ocean surface roughness, modifying the radar cross-section of the ocean and the magnitude of the backscattered power. Scatterometers measure this backscattered power, allowing estimation of the normalized radar cross section (σ_o) of the sea surface. Backscatter cross section varies with both wind speed and direction when measured at moderate incidence angles. Multiple, collocated, nearly simultaneous σ_o measurements acquired from several directions can thus be used to solve simultaneously for wind speed and direction.

The SeaWinds instrument uses a rotating dish antenna with two spot beams that sweep in a circular pattern. The antenna radiates microwave pulses at a frequency of 13.4 GHz across broad regions on Earth's surface. The instrument will collect data over ocean, land, and ice in a continuous, 1,800 kilometer-wide band centered on the spacecraft's nadir subtrack, making approximately 1.1 million ocean surface wind measurements and covering 90% of Earth's surface each day.

The SeaWinds instrument on ADEOS-II is an active microwave radar designed to measure electromagnetic backscatter from wind roughened ocean surface. ADEOS-II/SeaWinds is a conically scanning pencil-beam scatterometer. A pencil-beam scatterometer has several key advantages over a fan-beam scatterometer; it has a higher signal-to-noise ratio, is smaller in size, and it provides superior coverage.

The SeaWinds ground system computers will produce wind measurements within 3 days of receiving raw data from the spacecraft, with no backlog, throughout the mission. SeaWinds data products currently include global backscatter data, 25 km resolution ocean wind vectors in the measurement swaths and gridded wind field maps.

As part of the SeaWinds project, NASA is also sponsoring a team of scientific investigators who serve as project advisors during the development of the instrument and ground data processing system and who will conduct research based on SeaWinds data. Their studies are expected to lead to improved

methods of global weather forecasting and modeling and possibly to a better understanding of environmental phenomena (such as El Niño) that greatly affect world economies.

3.1 Principles of Operation

Spaceborne scatterometers transmit microwave pulses to the ocean surface and measure the backscattered power received at the instrument. Since the atmospheric motions themselves do not substantially affect the radiation emitted and received by the radar, scatterometers use an indirect technique to measure wind velocity over the ocean. Wind stress over the ocean generates ripples and small waves, which roughen the sea surface. These waves modify the radar cross section (σ_o) of the ocean surface and hence the magnitude of backscattered power. In order to extract wind velocity from these measurements, one must understand the relationship between σ_o and near-surface winds – this relationship is known as the geophysical model function.

The SeaWinds scatterometer design used for SeaWinds is a significant departure from the fan-beam scatterometers flown on previous missions (Seasat SASS and NSCAT). SeaWinds employs a single 1-meter parabolic antenna dish with twin offset feeds for vertical and horizontal polarization. The antenna spins at a rate of 18 rpm, scanning two pencil-beam footprint paths at incidence angles of 46° (H-pol) and 54° (V-pol). The transmitted radar pulse is modulated, or “chirped”, and the received pulse (after Doppler compensation) is passed through an FFT stage to provide sub-footprint range resolution. The range resolution is commandable between 2 km and 10 km, with the nominal value set at about 6 km. The nominal pulse repetition frequency is 187.5 Hz (also commandable). Each telemetry frame contains data for 100 pulses. Signal and noise measurements are returned in the telemetry for each of the 12 sub-footprint “slices.” Ground processing locates the pulse “egg” and “slice” centroids on the Earth’s surface. The σ_o value is then computed for both the “egg” and the best 8 of the 12 “slices” (based on location within the antenna gain pattern).

SeaWinds generates an internal calibration pulse and associated load pulse every half-scan of the antenna. In ground processing, the load pulses are averaged over a 20-minute window, and the cal pulses over a 10-pulse (approximately 18-second) window, to provide current instrument gain calibration needed to convert telemetry data numbers into power measurements for the σ_o calculation.

SeaWinds “programmability” includes commanding of major mode selection and range resolution, antenna spin rate and PRF, and the ability to uplink new Doppler compensation and range tracking tables as changes in the orbit occur, or to conduct special engineering tests. Mode changes will be made periodically to obtain additional calibration data, and special command sequences will be used during the early Cal/Val checkout phase.

3.2 Operating Modes

Mode 0: Wind Observation Mode

Wind observation mode is the primary science mode for SeaWinds, and will be in effect more than 95% of the time.

Mode 1: Receive-Only Mode

In Receive-only mode, the transmitter is turned off while the receiver collects data at the antenna ports. This mode will be used during Cal/Val to assess radio frequency interference and internal receiver biases. No science data is returned.

Mode 2: Continuous Calibration Mode

In Continuous Calibration mode, SeaWinds performs only calibration/load cycles in place of normal pulse transmission cycles. This mode provides the most accurate receiver calibration data, and will be used periodically throughout the mission. No science data is returned.

Mode 3: Standby Mode

Standby mode is the initial power-on mode of the SeaWinds instrument. The high-voltage power supply (HVPS) is turned off, and therefore no science data is returned.

3.3 Range Resolution Modes

The SeaWinds antenna footprint is an ellipse approximately 25-km in azimuth by 37-km in the look (or range) direction. Signal processing provides commandable variable range resolution of approximately 2- to 10-km.

The nominal resolution is approximately 6 km—an effective range gate of 0.5 msec. Table 3.1 illustrates that the actual range resolution is different for the inner and outer beams. Please note that there are two other default resolutions if the instrument resets.

Table 3.1 Range Resolution Modes

SES FFT Binning Table			
Binning arrangement: 10 Center slices at 1 resolution, 2 “guard” slices at edges to give >~ 150 kHz BW.			
	Bin BW =		
	0.46	B bin Res =	A bin Res =
ECR agrred w/ ESys 11/04		0.34	0.39

Eff Gate	Bins/Centr	Bins/Guard	BW ofBW	ofTotal	B,	B,	A,	A,	B, #	CenA, #	Cen
Width	10	Centr	10 Guard	BW	Centr	Guard	Centr	Gurad	slices	in 35	in 35
(msec)		Slice	(kHz)	(kHz)	(kHz)	(km)	(km)	(km)	(km)	km	km
0	1	1	4.62	0.92	5.54	0.34	0.34	0.39	0.39	103.5	90.8
0.1	5	125	23.10	115.48	138.57	1.69	42.29	1.93	48.16	20.7	18.2
0.2	10	125	46.19	115.48	161.67	3.38	42.29	3.85	48.16	10.3	9.1
0.3	15	100	69.29	92.38	161.67	5.07	33.83	5.78	38.53	6.9	6.1
* 0.4	28	75	129.33	69.29	198.62	9.47	25.37	10.79	28.90	3.7	3.2
**0.5	18	100	83.14	92.38	175.52	6.09	33.83	6.94	38.53	5.7	5.0
3*0.6	23	85	106.24	78.52	184.76	7.78	28.76	8.86	32.75	4.5	3.9
4*0.7	28	75	129.33	69.29	198.62	9.47	25.37	10.79	28.90		

Effective Gate Width = Range Gate - Pulse Length.

* SES Default (instrument startup; SES reset?)

** "Nominal" (6 km)

3* CDS Default (startup/POR)

4* Undefined states go to Default = (?, 0.6[3*])

4 Data Processing Overview

This section describes the overall design and functionality of the ground processing system for the SeaWinds data from ADEOS-II. The data flow diagram in Figure 4.1 shows the principal segments of the ground system, which include the NASDA Ground Network, the Earth Observing Center (EOC), the SeaWinds Processing and Analysis Center (SeaPAC) at JPL, and the PO.DAAC.

The ADEOS-II Mission Operations Interface Specification (MOIS Common Part version 1.0, May 2001, AD2-EOC-96-054) contains a more thorough description of these and other ground systems. The parts most relevant for SeaWinds data:

NASDA/EOC :

- receives raw data from the ground stations.
- sends AMSR Level 1A data to PO.DAAC.
- sends SeaWinds Level 0, Housekeeping Source Packet, Processed DMS data to SeaPAC.

JPL/SeaPAC:

- receives data from PO.DAAC and EOC.
- processes data into higher level SeaWinds products.
- sends SeaWinds products to PO.DAAC.

JPL/PO.DAAC:

- receives AMSR L1A data from EOC, sends them to SeaPAC, and stores them for a limited time.
- receives SeaWinds data from SeaPAC, archives them (except for near-real-time data), and distributes data products.

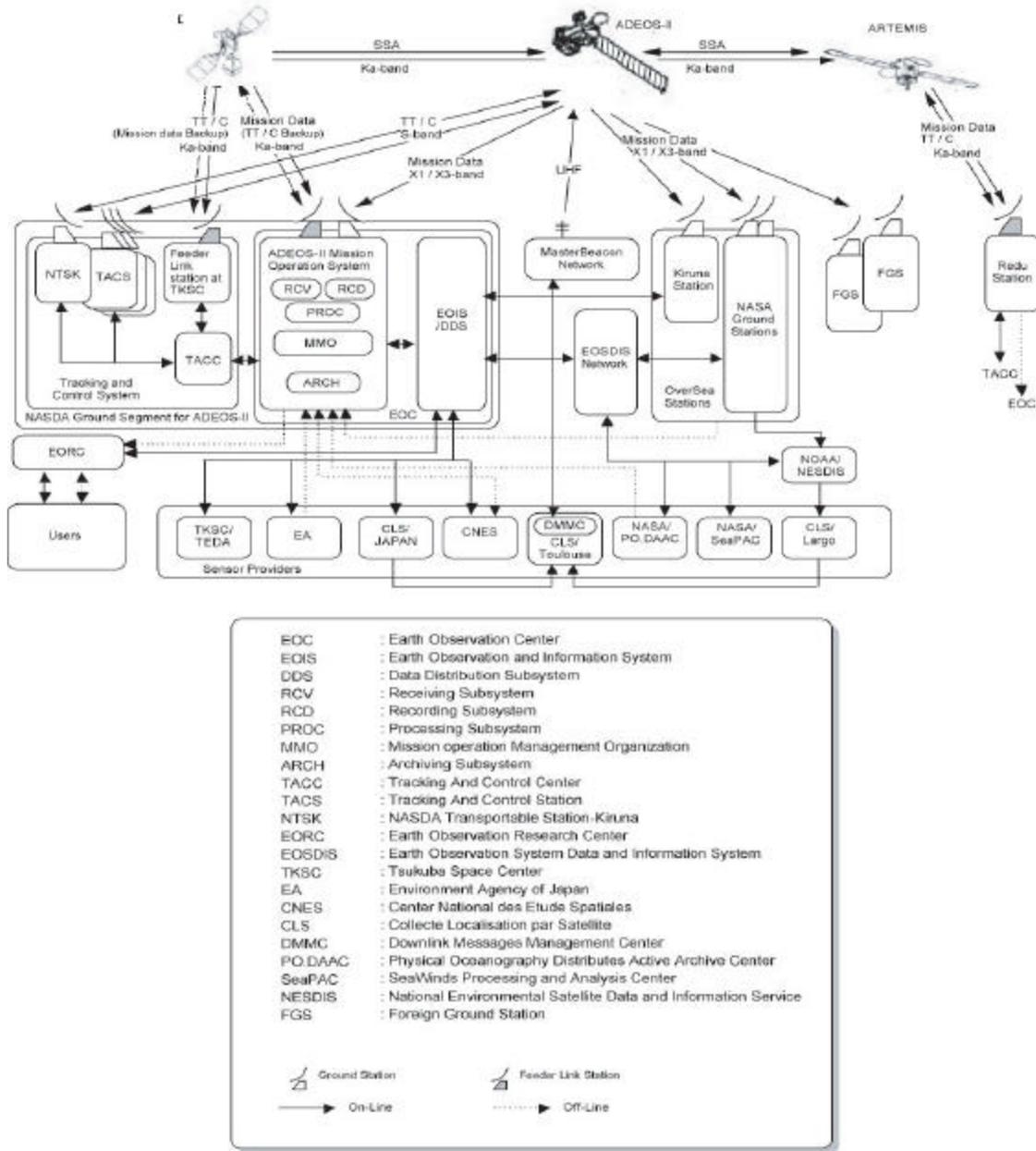


Figure 4-1: ADEOS II Data Flow

4.1 NASDA Ground Network and Mission Operations

The NASDA Ground Segment for ADEOS-II consists of the ADEOS-II Mission Operation System, the ADEOS-II related part of Earth Observation Information System (EOIS) and the ADEOS-II related part of Tracking and Control System.

4.2 Mission Operations Center

4.2.1 ADEOS-II Mission Operation System

ADEOS-II Mission Operation System, located at the Earth Observation Center (EOC) in Hatoyama, is the main planning organization for ADEOS-II mission operations and consists of the Mission operation Management Organization (MMO), the ADEOS-II Data receiving subsystem, data recording subsystem, data processing subsystem (including data inspection and evaluation subsystem), and data archiving subsystem. In this role the ADEOS-II Mission Operation System makes the operation plan of ADEOS-II onboard instruments based on the operation requests from sensor providers and NASDA PIs. Sensor providers such as the SeaWinds project can request the mission operation of their sensor and NASDA PIs can request mission operation of GLI (observation area of GLI 250 m and tilting operation). ADEOS-II Mission Operation System also schedules data downlinks and plans mission data recorder operations (tape management).

The ADEOS-II Mission Operation System serves as a Feeder Link Station for DRTS which is the Inter Orbit Communication Satellite (IOCS via Ka-band), as a Direct Downlink Station (X-band), as a Direct Transmission Station (UHF), and as a backup Tracking Telemetry and Command Station (TT&C).

In addition, The ADEOS-II Mission Operation System archives all Raw data, POLDER level 0 data and high level standard products for NASDA instruments, processes all mission data to Level 0, processes house keeping data of all sensors, and processes NASDA sensor data to standard products. The ADEOS-II Mission Operation System exchanges mission operation information files, Level 0 data and near real time products with the Sensor providers and related organizations using the handshake protocol developed for ADEOS-II satellite data transfers and specified in Network Interface Control Document Between NASDA and related agencies for the ADEOS-II Project. Finally, the ADEOS-II Mission Operation System obtains higher level products from the sensor on a request basis.

4.2.2 Earth Observation Information System/Data distribution and Management Subsystem (EOIS/DDMS)

NASDA's DDMS portion of the EOIS at the EOC provides network services for ADEOS-II operations, distributes standard product data sets and catalog information to users, and provides catalog system interoperability with EOSDIS. Additionally, Data Distribution Subsystem (DDS) is a part of DDMS and the primary interface for ADEOS-II mission operations information and data flows between EOC and related agencies using network.

4.2.3 Tracking and Control System

Tracking and Control System consists of the Tracking And Control Center (TACC) , the Feeder Link Station at Tsukuba Space Center (TKSC), the Tracking And Control Station (TACS) and the NASDA Transportable Station-Kiruna (NTSK). The TACC, located at TKSC, verifies the EOC mission operations plan against satellite constraints and generates the satellite commands. Commands are transmitted from TACC to the satellite through the Feeder Link Stations at the TKSC or TACS/NTSK.

TACC acquires the satellite engineering telemetry and ranging data using the Feeder Link Station at TKSC or TACS/NTSK for orbit determination. TACC evaluates these data and monitors the safety of the instruments and activates emergency safing procedures according to the Spacecraft Orbital Operations Handbook (SOOH) instructions. Additionally, TACC processes Doppler tracking data to provide predict and definitive satellite ephemeris.

Additionally, TACC will use Redu station to transmit commands to ADEOS-II and acquire satellite engineering telemetry from ADEOS-II via ARTEMIS when ADEOS-II satellite is not within DRTS visible contact. TKSC serves as a backup Feeder Link Station for the IOCS to acquire the mission data.

4.2.5 Overseas Stations

(a) NASA/NOAA Ground Network

The NASA/NOAA Ground Network (NGN) is the NASA management activity for the coordination of data acquisition from passes not available to EOC at Hatoyama, Japan or Kiruna, Sweden. The NGN Data Acquisition Stations (NASA Ground Stations) consist of Alaska SAR Facility located at Fairbanks, Alaska and Wallops Flight Facility at Wallops Island, Virginia.

In mode 1 operation, the NASA Ground Stations acquire the GLI 250 m data via X1 band and the Mission Real-Time (MRT) data via X3 band. Each station processes the ADEOS-II/ARGOS DCS (hereinafter referred as “DCS”) and GLI 1km real-time data to level 0 data. The DCS level 0 data is transmitted to EOC and the DCS and GLI 1km level 0 data to NOAA/NESDIS on a near real time basis via EOSDIS network. The raw GLI 250 m data is transmitted to EOC by media.

In mode 2 operation, the NASA Ground Stations acquire the MDR data, GLI 250 m data and/or ODR data via X1 band and the MRT data via X3 band. Each station processes the MDR data (except for POLDER data) and the DCS, GLI 1km real-time data to level 0 data, and transmits the level 0 data to related agencies on a near real-time basis via EOSDIS network. The raw MDR data , GLI 250 m and/or ODR data is transmitted to EOC by media.

Additionally, NASA ground stations process Dynamics Monitoring System (DMS) and Visual Monitoring System (VMS) real time data to level 0 data and transmit them to EOC using network in both mode 1 and mode 2 operation on a request basis from NASDA.

(b) Kiruna Station

Kiruna Station serves as a Direct Downlink Station of NASDA.

In mode 1 operation, the Kiruna Station acquires the GLI 250 m data via X1 band and the MRT data via X3 band. Kiruna station processes the DCS realtime data to level 0 data, and transmits the level 0 data to EOC on a near real-time basis. The DCS level 0 data is forwarded to CLS/Japan and NOAA/NESDIS. The raw GLI 250 m data is transmitted to EOC by media.

In mode 2 operation, the Kiruna Stations acquires the MDR data, GLI 250 m data and/or ODR data via X1 band and the MRT data via X3 band. Kiruna station processes the MDR data (except for POLDER data) and the DCS real-time data to level 0 data, and transmits the level 0 data to

EOC and related agencies on a near real-time basis through EOIS/DDS. The GLI 1km level 0 data generated at Kiruna station is processed to level 1 data at EOC for selected areas and bands and the data is transmitted to NOAA/NESDIS using network through EOIS/DDS on a near real time basis. The raw MDR data, GLI 250 m and /or ODR data is transmitted to EOC by media.

Additionally, Kiruna station processes DMS and VMS real time data to level 0 data and transmits them to EOC using network in both mode 1 and mode 2 operation on a request basis from NASDA.

4.3 SeaWinds Processing and Analysis Center (SeaPAC)

The SeaWinds Processing and Analysis Center (SeaPAC) at JPL is responsible for the reception of telemetry data, production and analysis of the science data products, and for delivery of the science products to the PO.DAAC for distribution. The SeaPAC consists of six principal subsystems, described in the following sections.

4.3.1 File Transfer Subsystem (FX)

The FX subsystem is responsible for all external data transfers into the SeaPAC. These include the reception of the science telemetry data from EOC, collection of ice edge data from the National Ice Center, and collection of NWP wind field data from NCEP. While the FX software can be run manually, most of its functions are completely automated.

4.3.2 Process Management Subsystem (PM)

The PM subsystem performs the database and automatic job scheduling functions for the SeaPAC, as well as providing a user interface for the SeaPAC operator. Using a rule-based algorithm PM is able to determine when all of the necessary input data for a particular job have become available, and can start that job automatically or inform the operator that the job is ready to be run manually.

4.3.3 Preprocessor Subsystem (PP)

The PP subsystem takes care of the initial processing of the Level 0 science telemetry, creating the basic input products for initiating the main science data processing. PP creates time correlation, ephemeris, and attitude files, creates the SeaWinds Level 0 files that are the input to the Level 1A processor, and also extracts and converts NWP data to the format needed by the Level 2B processor

4.3.4 Level Processor Subsystem (LP)

The LP subsystem is the heart of the science processing, implementing the conversions from Level 0 telemetry up through the Level 3 wind vector products. LP consists of five main programs, one each to produce L1A, L1B, L2A, L2B and L3 data in sequence. LP software incorporates and implements all

of the science algorithms, and creates the HDF data products delivered to PO.DAAC and to the science community.

4.3.5 Engineering Analysis Subsystem (EA)

The EA subsystem has the primary responsibility to monitor the instrument health and safety. EA focuses mainly on the Level 1A data to perform trend analyses on key instrument and spacecraft temperatures, voltages, and other engineering parameters.

4.3.6 Science Analysis Subsystem (SA)

The SA subsystem performs the primary QA and data analysis functions for the SeaPAC. SA is concerned with assuring that the science algorithms as implemented in the LP are performing correctly, and making algorithm corrections and refinements as needed. SA monitors the science data quality throughout the mission. QA reports are provided with all data products.

4.4 Physical Oceanography DAAC

- The Physical Oceanography Distributed Active Archive Center, (PO.DAAC), receives AMSR L1A data from EOC, sends them to SeaPAC, and stores them for a limited time.

PO.DAAC also receives the science data from the SeaPAC, archives the data, and distributes Level 1B, Level 2A, Level 2B and Level 3 to the SeaWinds science community. PO.DAAC also acts as the principal long-term archive for all telemetry, Level 0, Level 1A and ancillary files collected during the SeaWinds mission.

5 Geophysical Algorithm Overview

5.1 Telemetry Processing

The principal input delivered to SeaPAC by EOC is the science telemetry packet file. The science telemetry packet file contains the raw telemetry produced by the scatterometer, consisting of status and engineering data, antenna position data and received power data and also the spacecraft telemetry, including GPS time correlation information, GPS ephemeris, and spacecraft attitude data.

5.1.1 Science Telemetry Processing (Level 0)

The SeaWinds mission telemetry is packetized by the CDS (Command and Data Subsystem). Each 100-pulse frame of Level 0 telemetry is contained in three consecutive telemetry packets. Level 0 processing by SeaPAC consists of checking for bad or missing packets, assembling the corresponding packet triplets into frame-records, and assigning a frame quality flag.

The telemetry chiefly contains spacecraft engineering and flight data. For the purposes of the science processing, the Level 0 processing is needed because it includes three critical sets of information:

- UTC Time Correlation: The data provided gives the relationship between the spacecraft clock and UTC.
- GPS state vectors (spacecraft ephemeris): this is provided as both the “raw” GPS vectors (with 64-bit precision) and a “smoothed” version produced by an on-board orbit propagator (at 16-bit precision).
- Spacecraft attitude: The attitude is provided as a set of four quaternions, which are converted to the classic roll, pitch, and yaw angles for subsequent processing.

The Level 0 processor produces the ephemeris and attitude files required for L1A and L1B processing adds a one-line time correlation record to the SCLK.UTC (spacecraft clock-UTC) file, and reformats the Level 0 data itself into HDF for use by Engineering Analysis.

5.1.2 Level 1A Processing

The Level 1A processing functions include time tagging of science telemetry frames, assignment of ephemeris and attitude information to each frame, conversion of data to engineering units, and extraction of calibration pulse data.

5.1.2.1 UTC Time Tagging

The process of deriving UTC time tags for instrument frames uses the TMDF time correlation data provided by ADEOS, which is based on ground station observations of the spacecraft clock counter versus UTC. The TMDF data includes a base UTC time and the corresponding spacecraft clock count, as well as a clock drift parameter in seconds of drift per second. The SeaWinds instrument time counter is synchronized to the spacecraft clock counter at every ascending equator crossing. Given the

TMDF data and the instrument time count for a particular frame, the UTC time tag for the frame is given by:

$$\text{UTC}(\text{frame}) = \text{base_time}(\text{UTC}_0) + \text{drift_rate} * (\text{instrument_time} - \text{S/C_clock_base}) / 32$$

The instrument timer and the ADEOS spacecraft clocks are both 32-Hz counters. Neither counter is expected to roll over during the lifetime of the mission, however both may be reset in the event of a spacecraft anomaly. In the case of a SeaWinds CDS reset, the instrument timer will also reset independently, but will be synchronized at the first succeeding ascending equator crossing. SeaWinds data between the CDS reset and the equator crossing will not be able to be time-tagged.

5.1.2.2 Ephemeris and Attitude Processing

Once the UTC time of the frame is known, the spacecraft location, velocity, and attitude at the frame time can be determined from the ephemeris and attitude files. For SeaWinds on ADEOS-II the GPS ephemeris and the spacecraft attitude data is provided in the PlatformControl Data (PCD) embedded in the Level 0 telemetry frame. The PCD data are subcommutated over 16 frames (8 seconds) providing one GPS ephemeris time and state vector (position and velocity) and 4 attitude states (roll, pitch, yaw, and their rates of change). The PCD ephemeris and attitude data is extracted during the Level 0 processing into separate files which are used in subsequent level processing. At each frame time the ephemeris is interpolated by a cubic spline. The attitude data (with a nominal interval of 2 seconds) is assigned using a "nearest-available dat" (NAD) algorithm. If the NAD entry is more than 4 seconds from the frame time, the appropriate frame quality flag bit is set and the values for roll, pitch, and yaw are set to zero.

In the event that the GPS ephemeris fails during flight, the ground system can use the ELMD (determined ephemeris) files provided by NASDA as an alternative. The ELMD is based on ground-based orbit determination from spacecraft tracking observations.

In the Level 1B processing the PCD attitude may be superseded by the results of the echo-tracking algorithm built into the Level 1B processor.

5.1.2.3 Engineering and Science Data Conversion

The Level 0 telemetry data that are needed for subsequent science processing are converted from the packed values to "real" values for the Level 1A output. Key information in the instrument status and engineering data (modes, voltages, temperatures, cal pulse locations, etc.) are extracted. The antenna position data (stored in telemetry as full 16-bit data number (DN) values for pulses 1 and 51, and as 8 bit differences for the remaining pulses) are converted to full DN values for the L1A output. The science data for the slice powers (stored as 12-bit pseudo-floating point values) are converted to full 32-bit integer DN values, and the noise data (stored as 16-bit pseudo-floats) are also converted to 32-bit integer DN's.

5.1.2.4 Calibration Pulse Products

An important internal product generated by the L1A processor is the Calibration Pulse file. The calibration pulse data embedded in the science data is used to obtain the current values of the receiver gain via the loopback and cold load data. These data are inherently noisy, and must be averaged before they can be used in the L1B σ_o computation. To simplify the processing at L1B, and to provide a useful engineering analysis product that avoids the need to re-extract the calibration data from telemetry, the calibration pulse file is generated by the L1A processor. Each record of the cal pulse file contains information about an individual calibration pulse/load pulse pair.

5.2 Level 1B Processing

5.2.1 Spacecraft Location and Attitude

The spacecraft location, velocity, and attitude are determined from the ephemeris and attitude files. The same cubic-spline ephemeris interpolator and LAD attitude algorithms that are also used in the L1A processing are used for L1B. The ephemeris is interpolated for the N-th pulse ($N=1 \dots 100$) at the “landing time”, i.e. when the pulse reaches the Earth’s surface:

$$\text{Pulse_time}(N) = \text{Frame_time} + N * \text{PRF_Cycle_Time} + \text{slant_range} / 2c$$

where c is the speed of light; the last term is the one-way travel time from the spacecraft to the surface. Because of the circular scan pattern of the instrument, the values of `slant_range` used for this calculation are essentially constant for each beam, to the level of accuracy required, so the value for the previous pulse is actually used.

5.2.2 Antenna and Cell/Slice Geometry

Once the spacecraft location and attitude have been determined, the location of the pulse footprint on the Earth’s surface can be computed. The antenna azimuth is measured clockwise from the forward direction (spacecraft X-axis). The antenna feeds point at look angles (relative to the nadir, Z-axis of the spacecraft) of 39.876° and 45.890° for the inner (H-pol) and outer (V-pol) beams, respectively. The boresight vectors for each feed are determined in the Earth Centered Rotating (ECR) coordinate system after correction for the spacecraft attitude. The intersection of the boresight vector with the Earth’s surface determines the location of the whole-pulse, or “egg” center. The resulting incidence angles for the two beams are approximately 45° for the inner beam, and 53.6° for the outer beam.

The location of the slice centers involves information about the resolution mode, the frequencies of the slice boundaries in the echo channel, and the shape of the antenna pattern. Starting from the boresight location, an iterative search algorithm is used to find the intersections of the slice boundaries along the peak “spine” of the along-beam antenna pattern. Once the boundary points are known, the locations of the slice centers can be interpolated, weighting by antenna gain to get the radiometric centroid of the slice.

SeaWinds on ADEOS-II is capable of generating σ_o measurements at a variety of resolutions, including the “spot” or “egg” footprint of the full beam, the “slice” footprint of individual range-resolution elements, and “composite” footprints made up of multiple slices falling in a wind vector cell.

The SeaWinds antenna footprint is an ellipse approximately 25-km in azimuth by 37-km in the look (or range) direction. Signal processing provides commandable variable range resolution of approximately 2- to 10-km.

5.2.3 Sigma0 and Kp

The computation of the radar backscattering coefficient, σ_o , is performed for each power measurement provided in the Level 1A data.

5.2.3.1 ADEOS-II/SeaWinds Instrument and Power Detection

The scatterometer transmits a sequence of RF pulses (5.4 msec interval) and measures the returned energy from the Earth surface plus the instrument thermal noise (signal-plus-noise energy). In order to estimate an accurate σ_o , it is necessary to extract the signal-only energy by subtracting the noise-only energy from the signal-plus-noise energy.

In the ADEOS-II/SeaWinds design, the signal-plus-noise and noise-only energies are measured simultaneously by the two receiving channels (also refer to as filters): echo and noise. The instrument periodically performs a calibration measurement sequence (“cal-pulse”) in which the transmit power is fed into the receiver through loop-back calibration to measure for radiometric calibration and a cold load is measured for thermal noise estimation. The cold load measurements relate echo channel noise-only energy to the noise channel noise-only energy. This reduces the number of unknown variables to signal-only energy and noise-only energy of the echo channel, which can be solved by two independent signal-plus-noise energy measurements. The noise filter bandwidth is 1 MHz and the echo filter bandwidth can vary from about 5.5 KHz to 198.6 KHz.

5.2.3.2 Signal Processing for High Resolution

The ADEOS-II/SeaWinds instrument achieves a resolution higher than the antenna footprint by transmitting a linear frequency-modulated chirp (LFMC) signal. The returned signal can be viewed as a superposition of scattering contributions from every point in the area illuminated by the antenna beam. Each contributing source is delayed by a slant range difference, which can be related to frequency by the chirp rate. The summed waveform, (i.e. the echo signal), is then multiplied by a LFMC reference signal with a conjugate phase. This step maps a distinct time delay of a received waveform to a corresponding baseband frequency shift in the echo filter.

The extent of the baseband frequency shift allowed depends on the difference of the two commanded parameters: pulse width and echo gate width. The echo gate width minus the pulse width is termed effective gate width and this determines the resolution. By design, the echo filter is divided into 12 bands. The centermost 10 are equally spaced, and the two outer edge bands are wider. The inner 10 bands are called slices. Figure 5.1 illustrates the noise filter and divisions of the echo filter. Also, see Table 3.1.

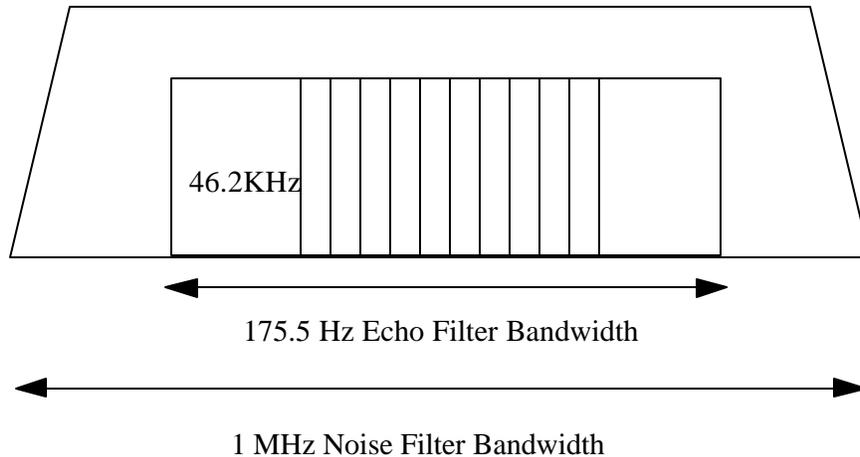


Figure 5-1 Illustration of Slice Resolution for 0.5msec Effective Gate Width

5.2.3.3 The Radar Equation and X-factor

The radar equation, which relates the radar return energy to the transmitted energy, the σ_o , and various electrical and geometric factors, is the basic relation used to compute σ_o . The critical problem is to extract σ_o , given the other parameters, by inverting the radar equation.

The radar equation consists of an integral over the scattering surface where the antenna gain, the receiver response, the slant range vary from point to point. As a first approximation, if σ_o is assumed constant over this range (essentially, a mean value), then the σ_o can be solved as a function of the return/transmit energy ratio and the gain-slant range integral. To avoid cumbersome numerical integration for every pulse in L1B processing, the integration is pre-computed and tabulated based on nominal orbit parameters and antenna measurement geometry. In conceptual terms, σ_o is given by:

$$\sigma_o = ((\text{signal} + \text{noise energy}) - \text{noise energy}) (X_{\text{int}} + \Delta f X_{\Delta f}) X_{\text{cal}}$$

where $\Delta f X_{\Delta f}$ is a first order correction to the nominal X_{factor} table accounting for attitude errors and deviations of the orbit from the nominal.

In addition, a perturbation table that can compensate for the errors in the integration due to the difference between the nominal and the actual geometric parameters (orbit and antenna geometry) is pre-computed. The combined nominal and perturbation table value gives the integral part of the X_{factor} , X_{int} . The calibration term of the X_{factor} , X_{cal} , together with X_{int} gives a complete conversion factor to relate the received energy to σ_o . This table-driven processing approach is very accurate and significantly reduces L1B processing time. These tables are a function of beam number, antenna azimuth angle, orbit position, slice number, and resolution mode.

5.2.3.4 The Kp Equation for SeaWinds

When a scatterometer measures the backscattering coefficient, σ_o , of the ocean surface, it does so with imperfect precision. Due to the instrument thermal noise and radar signal fading effects, the estimates of σ_o will be noisy. In scatterometry, measurement variations of this type are referred to as “communication noise”. A parameter commonly used to indicate the magnitude of the communication noise is Kpc, which is defined as the normalized standard deviation of the echo return energy:

$$kpc = \frac{\{Var[P_s]\}^2}{P_s} \quad (1)$$

where P_s is the expected echo return energy and $Var[P_s]$ is the variance of the echo return energy.

Kpc is a function of the instrument signal processing parameters and the return signal-only to noise-only energy ratio (SNR). It can be written as:

$$kpc^2 = kpc_A + \frac{kpc_B}{SNR} + \frac{kpc_C}{SNR^2}. \quad (2)$$

Kpc_A, kpc_B, and kpc_C are known as the Kpc coefficients. They are functions of the instrument antenna pattern, illumination geometry, modulation format, transmit pulse modulation, and receiver filter characteristics.

Although there are some small corrections for the digital processing used in SeaWinds, the analog Kpc model is adequate and clearer for explanatory purposes.

The analog Kpc coefficient derivation, as employed in the Seasat scatterometer (2), assumes that the bandwidth of each individual slice is narrow so that the power spectral density is flat over the slice bandwidth. Then it can be shown that the Kpc_A, Kpc_B, and kpc_C can be well approximated by the following expressions:

$$kpc_A = \frac{1}{B_s T_p} \quad (3)$$

$$kpc_B = \frac{2}{B_s T_g} \quad (4)$$

$$kpc_C = \frac{1}{B_s T_g} \sqrt{\left(1 + \frac{B_s}{B_n}\right)} \quad (5)$$

where,

B_s = Bandwidth of the individual slices.

B_n = Bandwidth of the noise filter (1MHz nominal).

T_p = Transmit pulse width.

T_g = Range gate width.

The egg Kpc formula results from a similar derivation and approximations:

$$kpc_A = \frac{1}{B_{3dB}T_p} \quad (6)$$

$$kpc_B = \frac{2}{B_{egg}T_g} \quad (7)$$

$$kpc_C = \frac{1}{B_{egg}T_g} \sqrt{\left(1 + \frac{B_{egg}}{B_n}\right)} \quad (8)$$

where,

B_{3dB} = the 3dB bandwidth of the egg.

B_{egg} = the sum of the individual slice bandwidths comprising an egg (nominally there are 10 slices in an egg).

5.2.4 SeaWinds Radiometer (SRad) Brightness Temperatures

During the Calibration/Validation phase of the SeaWinds on QuikSCAT mission, a complete characterization of the instrument noise sources led to the development of a model for transforming the instrument noise measurement for each scatterometer pulse into an apparent brightness temperature (Tb). Much of the data used for this characterization was obtained during two periods when SeaWinds on QuikSCAT was commanded into Receive-Only mode, one early in the mission (early July 1999) and one two-day period in November 1999 (during the Leonid meteor shower). These Tb measurements at both Hpol (from the inner beam) and Vpol (from the outer beam) are relatively noisy due to the fact that the scatterometer is not an optimal radiometer; however, they are sufficiently accurate to aid in rain detection and rain flagging in later wind processing, and to distinguish ice from ocean (and even first-year ice from multi-year ice).

The SRad brightness temperature model is applied during the Level 1B processing, when the Level 1A noise measurements and calibration data are available, along with various other instrument calibration parameters that are needed in the model. The Tb measurements are provided for the full pulses (all slices combined within each pulse) only.

5.3 Geophysical Product Processing

The Level 2A and 2B processing algorithms accept wind observation mode data only.

5.3.1 Level 2A Algorithms

The Level 2A algorithm processing can use either the pulse σ_0 data or the range-resolved “slice” σ_0 measurements from the Level 1B file. In the former case (which will be the initial Cal/Val baseline product), the σ_0 pulses are grouped into wind vector cells. In the case of the “slice” σ_0 data, a further step of “compositing” is done to synthesize σ_0 measurements at approximately the resolution of the WVC grid. In addition to grouping, each σ_0 is given an attenuation correction, and land or ice flags, as determined from maps.

5.3.1.1 Sigma0 Grouping

The σ_0 grouping algorithm prepares the SeaWinds σ_0 data for wind retrieval processing. The data contained in the Level 1B product is grouped by geographic location into wind vector cells (WVC). The grouped σ_0 data is saved in WVC rows in the Level 2A product.

The primary function of the σ_0 grouping algorithm is to re-order the Level 1B sensor data from time-ordered data frames into a primarily spatially-ordered (also time-ordered, but in an average sense) data set. The first step is to compute the subtrack bin coordinates WVC_I and WVC_J for each σ_0 cell. These coordinates describe the location of each σ_0 cell on the spacecraft swath in terms of along-track and cross-track distances. The (WVC_I, WVC_J) pairs, computed for a 25 km resolution grid, are used to assign σ_0 data to particular locations on the wind vector cell grid in preparation for wind retrieval. Unlike NSCAT, the expected number of σ_0 cells per WVC is not constant, due to the circular scan of the SeaWinds instrument. To minimize the L2A data volume, the σ_0 cell data are stored as “lists” for each WVC row, with each list indexed by the “cell_index” array to indicate the crosstrack WVC membership of the data.

5.3.1.2 Sigma0 Compositing

The σ_0 slices from the same pulse, which are assigned to the same WVC, are assembled into “composite” σ_0 values. The compositing process is essentially a weighted average of the slice σ_0 data using the X-factor values generated in the Level 1B processing for each slice. Similarly, composite cell locations, azimuth angles, incidence angles, and Kp coefficients are averaged to produce the full set of auxiliary data required for each composite σ_0 by the wind retrieval algorithm. Full details of the σ_0 compositing algorithm can be found in the [SeaWinds Algorithm Specifications](#).

5.3.1.3 Climatological Atmospheric Attenuation

The radar signal is attenuated as it passes through the Earth’s atmosphere. To correct for this effect, an atmospheric attenuation correction, based on the climatology provided by Wentz (1996), is applied to

the σ_o values. In SeaWinds L2A processing, the monthly $1^\circ \times 1^\circ$ mean two-way nadir attenuation is spatially and temporally interpolated to the σ_o location and converted to a line-of-sight attenuation.

The Wentz climatology is based on eight years of SSM/I ocean data. These passive microwave observations were used to estimate the mean monthly columnar water vapor, which was converted to water vapor attenuation. To obtain total atmospheric attenuation, oxygen and cloud attenuation, both rather small, were added to the water vapor attenuation. Atmospheric attenuation over land and ice were obtained from the NASA Water Vapor Project data set. By combining the ocean and land/ice attenuations, a monthly climatology of global mean atmospheric attenuation was produced. Details can be found in Wentz (1996). It should be noted that the effects of rain are not included in this correction.

The atmospheric attenuation, in dB, is computed in L2A and used in L2B to correct the σ_o values prior to wind retrieval. The correction is listed in the L2A product as a separate item, but is not applied to the σ_o data in the L2A product.

5.3.1.4 Surface Flags

After the σ_o data have been assigned to a WVC, each cell is checked for land and sea ice. The land map used is the same CIA land-sea map used for NSCAT. The sea ice mask is generated from weekly National Ice Center ice edge data. Both the land and ice flagging algorithms check the center of the σ_o cell (pulse or slice) against the land-sea map and the ice mask. For composite σ_o data, the surface flags on the slices that make up the composite are examined; if any one slice is flagged as non-ocean, the entire composite is similarly flagged.

5.3.1.5 SRad Brightness Temperatures

The SRad brightness temperatures (T_b) from the Level 1B data are grouped on the wind vector cell grid in the same way as the σ_o and related data. In order to reduce the inherent relative noisiness of the T_b data, the T_b measurements within a WVC are averaged by polarization. There are typically 4-8 T_b measurements of each polarization in each WVC. In addition to the mean T_b values thus obtained, the standard deviations and the number of measurements for each polarization are provided in the Level 2A data.

The locations of the T_b measurements are not explicitly provided in the Level 2A product; however, the locations may be generated from the Level 2A data by averaging the locations of the σ_o data within the WVC, which are provided in the data. Alternatively, the WVC locations from the Level 2B data, which are those same σ_o centroid locations, may be used in conjunction with the Level 2A T_b data.

5.3.2 Level 2B Processing

The Wind Vector Cell Preparation algorithm operates on a row of WVC values, passed from the Grouping algorithm, one WVC at a time. It then must determine if there is sufficient data of sufficient quality to perform wind retrieval. This algorithm checks each WVC to determine the data counts (total

and by beam), quality flags, and surface flags. It then computes the centroid of the σ_o locations to give a WVC location (latitude/ longitude; the binning grid is essentially “thrown away” at this point), and passes the “good” data to the Wind Retrieval algorithm. Upon return from wind retrieval, the ambiguous wind vector data is placed in the Level 2B output buffer.

5.3.2.1 Wind Retrieval

The radar backscatter (σ_o) describes the state of the scattering surface observed at the particular geometry (azimuth, incidence angle). Two or more observations at different look angles are required to determine a finite set of wind vector solutions.

The model function relating σ_o and near-surface wind velocity can be written as

$$\sigma_o = F(|U|, \chi, \dots; f, p, \theta) \quad (2)$$

Where σ_o is the normalized radar cross-section of the ocean surface, $|U|$ is wind speed, χ is the azimuth angle in the horizontal plane between the vector wind and the radar, and (...) represents the (presumed small) influences of other geophysical phenomena on σ_o . The parameters f , p , and θ are the radar frequency, polarization (horizontal or vertical), and incidence angle (the angle in the vertical plane between the incident radiation and the local vertical), respectively.

The azimuthal modulation of σ_o allows scatterometers to measure wind direction as well as wind speed. The largest azimuthal variations of σ_o are the “upwind-crosswind modulation”, resulting in backscatter cross-sections that are largest at upwind and downwind and smallest at crosswind angles, and the “upwind-downwind asymmetry”, resulting in different cross-sections for upwind versus downwind (with upwind values generally larger). As σ_o at fixed $|U|$ and theta must be periodic with respect to χ (with period 2π), it is natural to model the azimuthal modulation as a Fourier series in χ .

The upwind-downwind modulation of σ_o , coupled with at least three collocated observations of σ_o differing in azimuth angle and/or incidence angle, in principle allows determination of a unique wind vector. In the case of $A_1=0$, corresponding to perfect upwind/downwind symmetry, a 180° ambiguity in wind direction cannot be eliminated. Even for small but nonzero values of A_1 , model function uncertainties and noise in the σ_o measurements lead to only moderate point-by-point skill in resolving directional ambiguities.

Due to the azimuthal variation of the model function, the objective function used to determine wind vector solutions has a number of local extrema, referred to as “ambiguities”. These ambiguities correspond to solutions at approximately the same wind speed, but with different directions. The values of the objective function at these ambiguities characterize the goodness-of-fit between the σ_o measurements and the model function. From the standpoint of estimation theory, the ambiguity at the global extremum of the objective function is the “best” estimate of the wind.

The characteristics of the objective function also depend on the specifics of the instrument design. A scatterometer with only two orthogonal beams, as in the case of the Seasat SASS, will always have two global extrema (i.e. ambiguities with equal values of J) approximately 180° apart. Based on estimation

theory alone, it is impossible to distinguish between these solutions, giving rise to a true upwind-downwind ambiguity. The introduction of additional azimuthal looks, as provided by the NSCAT mid-beam, or the azimuthal difference between the inner and outer beams for SeaWinds, helps to break this symmetry, yielding a single global extremum. For SeaWinds, the azimuth mix varies at each cross-track location due to the dual circular scans. The nadir region, formerly unavailable to either SASS or NSCAT, has fore and aft looks that are nearly 180° apart. At the extreme edges of the swath, the outer beam fore and aft looks are all nearly in the same direction, making the extreme edges unsuitable for wind retrieval.

The concept of azimuthal diversity among the measurements, that is, the spread of azimuth looks among the σ_o measurements in the WVC, is applied in deciding the suitability of the WVC for wind retrieval. For SeaWinds, the azimuthal diversity criterion that is used is that the azimuth looks must have a range greater than or equal to 20° in order to allow wind retrieval to proceed.

The SeaWinds wind retrieval algorithm uses a maximum-likelihood estimator (MLE) as the objective function for determining wind vector solutions. The MLE is defined by:

$$J = - \sum_{i=1}^N \frac{(\mathbf{s}_{oi} - \mathbf{s}_m(u, \mathbf{c}_i))^2}{\text{Var}(\mathbf{s}_m)_i}$$

where σ_{oi} are the backscatter measurements, $\sigma_m(u, \chi_i)$ are the model backscatter values corresponding to the measurements, and $\text{Var}(\sigma_m)_i = \alpha\sigma_{mi}^2 + \beta\sigma_{mi} + \gamma = (K_{pi}^2\sigma_{mi}^2)$ are the measurement variances. The minus sign is chosen such that the local maxima of J correspond to wind vector solutions.

An accurate model function is essential to deriving ocean wind vectors from scatterometer measurements. Varieties of Ku-band models exist, some of which are derived from scattering theory, and some which are empirically derived. The tabular form of the model function, using a table of real space (non-dB) σ_o values, is used for SeaWinds, with modifications for the incidence angle range and the resolution of the table in azimuth and incidence angle. The initial post-launch model function used for SeaWinds is the QSCAT-1 model. QSCAT-1 has been recalibrated for wind speeds above 16 m/s to speeds derived from SSM/I F13, and this recalibration (**QSCAT-1/F13**) was used in L2B processing starting in July 2006.

5.3.2.2 Ambiguity Removal

The SeaWinds ambiguity removal algorithm uses a modified median filter technique to select a unique wind vector out of a set of ambiguous wind vectors at each wind vector cell.

The wind retrieval algorithm computes a set of wind vectors together with their relative likelihoods for each wind vector cell. The solution closest to the true wind is called the “closest” solution and all the wind vector solutions found in each WVC are referred to as “ambiguities”. Based on simulated data,

there are usually two to six ambiguities per WVC. Typically, around 60% of the most likely ambiguities are the closest and around 30% of the most likely ambiguities are opposite to the closest. The objective of the ambiguity removal algorithm is to choose the “closest” solution from the list of “ambiguities”. This objective is equivalent to detecting cases where the ambiguity with the highest likelihood is not the closest solution and selecting the closest solution out of the rest of the ambiguities.

Simulations and preliminary analysis of SeaWinds data show that in the nadir swath, (200km either side of nadir), there are usually less than four ambiguities and occasionally there is only one ambiguity. The directional uncertainties in this nadir region can be rather large. This is a result of the σ_0 distribution produced by the instrument design. In the nadir region, the “closest” direction may be rather far from the truth, but the true direction is usually within the uncertainty interval about the closest vector.

Median filter techniques were first introduced in 1974 to smooth time series data. They were later applied to image enhancement. The median of a group of data values is that value for which there are equal numbers of data values of greater magnitude and lesser magnitude. An important characteristic of the median filter is that it ignores extreme values. Therefore, the median filter has the advantage of eliminating impulses while preserving edges. In an ambiguous wind field, the majority of the ambiguities with highest likelihood are either in the same direction or in the opposite direction as compared to the true wind. This is equivalent to an image with impulsive noise on which a median filter can be used effectively.

The conventional definition of the median can only be applied to non-circular (i.e. linear and scalar) data in which the ordering of the values is obvious. The pixel brightness levels in an image are an example. For circular data (such as directions) or vector data, the conventional definition of median fails because the order of numbers cannot be specified, and the median itself can be ambiguous. An alternative definition of median is used here. The median of a set of data $x(1), x(2), \dots, x(N)$ is defined as the number $x(M)$ which minimizes:

$$\sum_{i=1}^N |x(M) - x(i)|$$

where $1 \leq M \leq N$.

This definition can be applied to circular and vector data as well as non-circular data. For non-circular data, it is equivalent to the conventional definition. The medians of circular and vector data calculated using the alternative definition have similar characteristics to the median of non-circular data, i.e. extreme and isolated data are ignored.

The measure used to describe the performance of the ambiguity removal algorithm is ambiguity removal skill, which is defined as the percentage of WVC values for which the wind vector selected by the ambiguity removal algorithm is also closest to the true wind. Likewise, instrument skill is defined as the percentage of WVC values for which the wind vector with the highest likelihood is the vector closest to the true wind. Instrument skill depends on the backscatter/wind model function, the wind retrieval algorithm, and design of the scatterometer (number of beams, signal-to-noise ratio, etc.).

In general, good ambiguity removal skill can be achieved when the average instrument skill is high. However, the overall skill alone does not provide detailed information. The success or failure of the ambiguity removal algorithm is determined by the occurrence of regions of low instrument skill. Broad patches of low instrument skill may occur in regions where the scatterometer SNR is low (far swath cells, low wind speeds) and/or at particular wind directions relative to the antenna beams where the model function and wind retrieval algorithm has difficulty distinguishing the relative likelihoods of the two principal ambiguities. This effect is referred to as “local” instrument skill; that is, how well the wind retrieval algorithm performs on smaller spatial scales.

For example, a uniform distribution of 60% local skill will result in an ambiguity removal skill of over 96%. On the other hand, a distribution composed of regions of half 40% and half 80% local skill may result in an ambiguity removal skill of 50%. In this case, the regions of 40% instrument skill resulted in 0% ambiguity removal skill and the regions of 80% instrument skill resulted in 100% ambiguity removal skill. Based on simulated NSCAT data, high algorithm skills (>96%) and randomly distributed errors can usually be reached when regions of low instrument skill are much smaller than the median filter window size.

The entire rev of data is maintained in memory at once, to prevent discontinuities in the selected fields. The algorithm begins with the field of “most likely” wind vectors as derived from the wind retrieval algorithm. The “most likely” vectors are those that represent the best fit to the model function. The wind vectors in a 7 x 7 filter window determine a median vector for the center cell. This median vector is compared with the ambiguities in that cell, and the closest ambiguity to the median is selected for use in the next iteration. The entire rev is filtered in this way. The process continues until it converges, i.e., when no new replacements of vectors have been made. The final selections are indicated in the Level 2B record by the WVC_selection entry. Tests of this algorithm with simulated wind data show that it selects the vector closest to the true wind 96% of the time, on average.

5.3.2.3 NWP Initialization of Ambiguity Removal

The baseline ambiguity removal algorithm for SeaWinds incorporates the Numerical Weather Product (NWP) initialization technique used for NSCAT-1 and NSCAT-2 processing. In this “nudging” technique, the median filter algorithm is initialized with either the first or the second ranked wind vector solution, whichever is closer to the direction of the NWP analysis field. The median filter algorithm then proceeds as described above to generate the final wind vector selections.

5.3.2.4 DIRTH Algorithms

At far swath, ambiguity removal skill is degraded due to the absence of inner beam measurements, limited azimuth diversity, and boundary effects. Near nadir, due to nonoptimal measurement geometry (fore and aft looking measurement azimuths approximately 180° apart), there is a marked decrease in directional accuracy even when ambiguity removal works correctly. Two algorithms were developed, direction interval retrieval (DIR) to address the nadir performance issue, and threshold nudging (TN) to improve ambiguity removal at far swath. The two algorithms work independently and need not be used together. However, both were used to obtain the DIRTH solutions, wind_speed_selection and wind_dir_selection, in the Level 2B product.

Please refer to Stiles [1999] for more information on the DIRTH algorithm

5.3.2.5 AMSR Processing and AMSR-based Sigma0 Corrections and Rain Impact

5.3.2.5.1 AMSR Calibration

AMSR L1A data produced by JAXA were obtained for SeaWinds use via PO.DAAC. The AMSR L1A data contains Earth-located antenna measurements (counts) and other calibration data required to convert the counts into antenna temperatures and finally into observed brightness temperatures (Tb). We found from comparisons of the mean AMSR Tb with WindSat Tb as a function of orbit position that a further calibration correction to the AMSR measurements was required to reduce ascending/descending biases that were present if we used the JAXA calibration alone.

5.3.2.5.2 Tb Resampling

The next step is to construct new sets of observations that have multiple frequencies at the same spatial resolution. We refer to this process as resampling. It is needed since radiometers of different frequencies using a common antenna produce different gain patterns on the Earth's surface (footprints with different spatial resolution). This complicates direct comparison of the measurements since the different frequency channels do not see identical scenes. Multifrequency observations cannot be used in the retrieval of geophysical parameters without *a priori* knowledge of their spatial variability (the well known nonuniform beamfilling problem).

We alleviate the resolution problem by constructing several spatially-consistent sets. The Backus-Gilbert method (see Algorithm Theoretical Basis Document - AMSR Level 2A Algorithm, Ashcroft and Wentz, 2000) can be used to bring the observations to a common resolution by either: i) spatial resolution enhancement (deconvolution) or ii) spatial averaging. The current algorithm employs spatial averaging since it permits noise reduction. The algorithm produces spatially consistent data sets, corresponding to the footprint sizes of the 6.9, 10.7, 18.7, 36.5 and 89 GHz channels.

The resampled observations are linear combinations of actual observations that fall within the “constructed” gain pattern by combining neighboring actual observations Tb_i with different relative weights a_i .

$$\hat{T}B = \sum_1^{21 \times 21} a_i \overline{Tb}_i$$

$$\overline{Tb}_i = \int Tb(\rho) G_i(\rho) dA$$

$$\hat{T}B = \int Tb(\rho) \sum_1^{21 \times 21} a_i G_i(\rho) dA$$

In the above equations ρ indicates a particular location $G_i(\rho)$ is the antenna gain pattern at that location that corresponds to the i^{th} observation; $Tb(\rho)$ is the brightness temperature at the location, TB is the reconstructed brightness temperature.

These sets of relative weights (coefficients) \mathbf{a} can be obtained via the Backus-Gilbert method. This method approximates a given function as a linear superposition of other functions. A significant obstacle in applying the method is that calculation of weighting coefficients requires the computation and inversion of large matrices. Because of that, its real-time application is computationally prohibitive. However, *a priori* information about the relative geometry of the actual observations allows the weighting coefficients to be calculated off-line. These weighting coefficients are unique for every position along the scan (depend on the relative geometry of the footprints) but do not vary from scan to scan. The real time resampling is then reduced to simply applying the weighting coefficients to the actual observations when the data is collected.

5.3.2.5.3 AMSR Geophysical Retrievals

The algorithm uses linear regression to retrieve the sea surface temperature (SST), the near-surface wind speed W , the columnar vapor V , and the columnar liquid L in a scheme very similar to the method proposed by Wentz and Meissner, 2000. What makes the current algorithm different from theirs is the approach taken for retrievals in rainy conditions. This involves the use of multiple retrieval databases selected based on the Rain Indicator. Sea surface conditions in rainy cases are estimated from the surrounding clear air cases instead of using climatological observations as proposed by Wentz. Sensitivity tests have shown that accounting for the specific surface conditions reduces the uncertainty in the retrieved total liquid. The Rain Indicator (RI) is computed directly from the brightness temperatures to show the likely intensity of rain.

For rainy conditions we have developed an algorithm (with the corresponding retrieval databases) that addresses in a new way the issues of non-uniform beam filling and hydrometeor structure uncertainty. The algorithm uses the RI to determine the intensity and degree of homogeneity of the rain within the satellite's Field of View (FOV). With this information in hand, it then selects the appropriate retrieval database to estimate the geophysical parameters of interest: sea surface temperature (SST), columnar water vapor (V), and columnar liquid (L). All of the retrieval databases were built based on a large number of observed atmospheric structures.

A more detailed description of how some of the main ingredients of the algorithm were developed is provided in [Veleva1].

5.3.2.5.4 Improved/corrected SeaWinds Sigma0s for Wind Retrieval

We developed, in parallel, two independent methods: physical and empirical, to estimate the effect of atmospheric attenuation and rain on scatterometer measurements as a function of the retrieved geophysical parameters. Of these, the empirical approach was chosen as the representative

SeaWinds/AMSR correction method after a lengthy parallel validation of the two approaches showed the empirical model to be somewhat more robust. Here we briefly describe both approaches.

5.3.2.5.5 AMSR-derived atmospheric attenuation and backscatter corrections

Physical Model Corrections

The scatterometer signal may be affected in three ways as it propagates through the atmosphere: the signal is attenuated by the rain, clouds and vapor in the atmosphere; the signal is augmented by the backscatter from rain droplets; the signal is augmented by the rain-induced roughening of the ocean surface (“splash”). It is very important to account for these three effects properly and to correct the σ_0 measurements before they are used to estimate wind vectors.

The first and second components of the atmospheric impact, the attenuation and precipitation backscatter, are estimated based on the AMSR retrievals of columnar liquid water, water vapor and sea surface temperature. Representative values in each WVC quadrant are computed as linear averages of the estimates from all AMSR observations that fall within the quadrant.

The third rain effect, the rain-induced surface roughening, is accounted for in the physical L2B algorithm as a function of the rain rate which is computed from the backscatter based on assumptions about the hydrometeor structure.

Details of the physical correction approach are described in [Veleva1].

Empirical Model Corrections

The empirical model is computed from AMSR geophysical parameters, SeaWinds scatterometer measurements, and coincident NCEP winds. The NCEP winds are employed to estimate equivalent rain-free backscatter values $AS_0(NCEP)$ for each SeaWinds scatterometer measurement $S_0(SeaWinds)$. The rain induced attenuation (multiplicative) and backscatter (additive) components are then determined as functions of SST, vapor, liquid, and antenna beam (H and V polarization). For each bin in the 4-D parameter space, the rain induced backscatter and attenuation are computed by regressing a line such that

$$S_0(SeaWinds) = AS_0(NCEP) + B$$

In order to reduce the inherent errors in the linear fits, an additional regression was performed. The A and B values from the original linear fits were themselves fit to polynomial functions of columnar liquid water L. This regression was performed separately for each SST and vapor bin and for each antenna beam. It is important to note that NCEP winds were only used in regressing the parametric model; once the model is computed, they play no role in estimating the correction to apply for each scatterometer measurement. Furthermore, constraints are applied to limit how much NCEP can influence the regression. For L=0, the additive rain-induced backscatter term is constrained to be zero, and the attenuation value is constrained to match the physical model. Because some regimes in the SST, V, L, and beam 4-D parameter space were undersampled, a

simpler 2-D L and beam-only model was regressed. This model was used whenever the sampling of the more complex model was deemed to be insufficient. For more details of the empirical rain correction method and a preliminary validation of the results achieved with this method see the supplemental package [Stiles1].

5.3.2.5.6 Sigma0 variance corrections from AMSR attenuation and backscatter

In addition to modifying the sigma0 values, the AMSR attenuation and backscatter coefficients are also used to revise the computation of the variance of each measurement which is employed in the Maximum Likelihood Estimation algorithm during wind retrieval.

The model for the variance correction is given by:

$$\text{Var}(\text{corr}) = A^2 \text{Var}(0) + 0.25 B^2$$

where $\text{Var}(0)$ is the “uncorrected” variance function of the model σ_0 :

$$\text{Var}(0) = \alpha \sigma_0^2 + \beta \sigma_0 + \gamma$$

and the coefficient (0.25) for the backscatter coefficient assumes that the uncertainty in the atmospheric backscatter is of the order of 50%.

To compute the corrected α , β , and γ from the values of kp_alpha , kp_beta , and kp_gamma given in the L2A data, we use the following:

$$\alpha (\text{corr}) = 1 + A^2 * (\text{kp_alpha} - 1)$$

$$\beta (\text{corr}) = A^2 * \text{kp_beta}$$

$$\gamma (\text{corr}) = A^2 * \text{kp_gamma} + 0.25 B^2$$

5.3.2.6 AMSR-derived Empirical Rain Impact on Scatterometer Winds

For each 25 km Wind Vector Cell (WVC) we estimated the impact of rain on the wind vector accuracy. These impact estimates describe the performance of the uncorrected Scatterometer only data set. However, because AMSR derived quantities were used to produce the impact estimates, they are included in the SWS/AMSR data set rather than the SeaWinds scatterometer-only data set. No estimate of the rain impact on the *rain corrected* data is included in either data set.

Two rain impact quantities are reported 1) rain induced speed bias in m/s, and 2) rain-induced cross track preference in degrees. Both values are reported as separate SDS data sets in the L2B files. The usual autonomous MUDH rain flag bit in the SWS/AMSR files is replaced with a new bit obtained by applying thresholds to the two impact quantities. These quantities are computed as a function of cross track index (CTI), average outer beam rain induced backscatter and attenuation coefficients (B and A),

and average outer beam Sigma0 value. These four parameters are computed for each WVC and used to look up the speed bias and cross track preference from a 4-D table.

The table is computed using co-located SeaWinds scatterometer only and NCEP wind vectors. In order to minimize the inclusion of systematic NCEP errors (if any) we apply offsets to the table so that rain-free ($B=0$) cells have zero impact. For each cell in the table the speed bias and cross track preference with respect to NCEP is computed. Cross track preference is defined to be how much closer to the cross track direction the scatterometer vector is than the NCEP vector. It is computed by subtracting the average angle between NCEP and cross track from the average angle between the Scatterometer only DIRTH wind vector and cross track.

The speed bias computation also employs the DIRTH wind vector. However, for high measured sigma0 (high wind speed) cells we found that comparison between NCEP and DIRTH gave us unbelievably high *positive* speed biases. We attributed this effect to statistical and resolution issues in the NCEP wind fields. To avoid this problem, we estimated the speed biases for high measured Sigma0 values using the A and B values and the geophysical model function; thus removing NCEP from the process. After values were computed for each bin in the table, a polynomial fitting mechanism was applied to smooth out sampling noise. The zeroth order coefficients in the polynomials were used to force the impact quantities to be zero for rain-free conditions. The rain flag bit was set whenever the speed bias is positive and greater than 2m/s OR the cross track preference is greater than 15 degrees. Flagging negative speed biases was determined to be counterproductive.

5.3.2.7 Autonomous (IMUDH) Rain Flagging

For this release we have revamped the autonomous rain flagging algorithm (MUDH) for the scatterometer only data set. The new version is called IMUDH where I stands for Impactbased. The algorithm is essentially the same, but it is trained using the impact flag bit mentioned in the previous section. In the past MUDH was trained using co-located SSM/I data. Various rain-dependent parameters were computed including SRAD brightness temperatures (V and H), normalized beam differences, first rank speed, first rank MLE, and first rank direction relative to cross swath. Two 4D rain probability tables were then computed; one for each of the dual-beam and single-beam portions of the swath. Different sets of 4 rain-dependent parameters were used to index each table. The probabilities were computed by estimating the fractions of WVCs falling into each bin that were labeled as “rain”. The difference between IMUDH and old MUDH is that for old MUDH “rain” means a co-located SSM/I columnar rain rate greater than 2 km mm/hr. For IMUDH “rain” means the AMSR-derived rain impact bit was set.

After the IMUDH tables are computed, four probability thresholds are chosen for spatially “isolated” and non-isolated flags, and for the single and dual-beam portions of the swath.

The IMUDH tables and thresholds are used to flag each WVC for rain in the following manner. For each WVC, the rain-dependent parameters are determined. One of the two IMUDH tables is chosen based on the location of the WVC in the swath. The rain dependent parameters are then employed to look up a rain probability in the table. If the probability is greater than the appropriate non-isolated

probability threshold, the WVC is provisionally flagged for rain. After each WVC has been examined once, a second “spatial filtering” pass is performed in which WVCs with few flagged neighbors are determined to be isolated. The flags of isolated WVCs are cleared unless their rain probability is greater than the isolated probability threshold.

The primary improvement of IMUDH over MUDH is in the reduction of the overflagging of high wind speeds. The overall flagging rate is also reduced from 5% to around 2%. This flagging rate was selected by examining various wind quality metrics for flagged and unflagged data with a variety of chosen flagging rates.

5.3.2.8 Wind Retrieval and Ambiguity Removal Algorithm Improvements

5.3.2.8.1 Improved model function for high wind speeds

A principal conclusion of the OVWST model function meeting at JPL in July 2005 (Yueh, 2005) was that the QSCAT-1 model underestimates winds over 20 m/s, and that the high-speed calibration of the QSCAT-1 model should be retuned to SSM/I. Freilich and Vanhoff have performed this adjustment to QSCAT-1 over the range 16-30 m/s using collocated QuikSCAT and SSM/I F13 measurements. The resulting adjusted model, “QSCAT-1/F13” has been used in the SeaWinds wind processing in this release.

5.3.2.8.2 Correction of retrieval algorithm to remove speed and direction artifacts

Freilich noted in 2003 that a distinct processing artifact existed in both the SeaWinds and QuikSCAT Level 2B wind speeds. If the wind speed histogram was created at very high resolution (0.1m/s) the histograms showed marked spikes at approximately 0.25 m/s intervals. This was attributed initially to the search step in the fine-resolution solution search algorithm; however, tests with other resolutions did not correct the problem.

Vanhoff and Freilich found that the effect was due to three key algorithm defects:

- (1) tri-linear interpolation of the model function table, (2) lack of robustness in the Newtonian peak-finding algorithm which located the optimum wind speed “ridge” in the MLE objective function, and (3) the 2-D fine search algorithm (as noted above). They recoded the wind retrieval algorithm to largely eliminate model function table interpolation, improved the peak-finding algorithm, and scrapped the 2-D search by applying the peakfinding algorithm at a finer search step in speed and direction. Elimination of the model function interpolation within the wind retrieval was enabled by a careful pre-interpolation of the table to a finer wind speed resolution (0.1 m/s) and using $\log(\sigma_0)$ vs $\log(\text{speed})$ to achieve a smoother result. The wind speed quantization effect has been eliminated in the current processing thanks to this change in the processing algorithm. A further artifact, this time in the wind direction histograms, was noted during the current

SeaWinds/AMSR development. This artifact is the occurrence of “cardinal-point” spikes in the DIRTH wind directions, which is due to the application of the DIRTH median filter to find a corrected wind direction. When one or more vectors with either the u or v component equal to zero (i.e. another cardinal-point direction) is present in the median filter window, and zero happens to be the median value for a component, the final DIRTH result for direction will also be a cardinal direction. This problem was exacerbated in the SWS/AMSR retrievals by the occurrence of zero-wind speed vectors resulting from AMSR over-correction for backscatter. We have reduced this problem by removing the zero-speed vectors from the median filter, and using double-precision ATAN2 to recover the direction from the component medians of u and v.

5.3.2.8.3 Re-introduction of log(Variance) in MLE objective function

The maximum-likelihood estimation (MLE) objective function used in the wind retrieval has been modified in the SeaWinds Level 2B. We have reintroduced the $\ln(\text{variance})$ term in the MLE:

- (1) Wind retrievals in which the majority of the σ_0 data are negative, as in the case where the AMSR backscatter corrections are large (i.e. the scatterometer is not really seeing the surface), resulted in wind speeds that were at or near 50 m/s without the $\ln(\text{var})$ in the MLE. With the term included the wind speed estimates are at or near 0 m/s.
- (2) In order to properly account for the attenuation and atmospheric backscatter corrections to the variance without biasing the results, the $\ln(\text{var})$ term was required.
- (3) The wind speed bias that was observed, and never well explained, with the QuikSCAT 25km slice-composite processing data in 1999, is removed by the use of the $\ln(\text{var})$ term. This is also true for the 12.5km slice processing. The $\ln(\text{var})$ term is required to place the 25km and 12.5km SeaWinds processing on a more or less equal footing. We have speculated that the $\ln(\text{var})$ term becomes important in cases where the “variance of variances” among the σ_0 measurements becomes significant. When the K_p of all of the measurements is about the same, the $\ln(\text{var})$ has little effect (which is why we abandoned it for the NSCAT-2 processing in 1998, and thereafter for QuikSCAT and SeaWinds). For 25km “egg” σ_0 , the $\ln(\text{var})$ effect is small, but when AMSR corrections are applied, or with slice-composite σ_0 with a wide range of K_p , the $\ln(\text{var})$ is needed to keep the estimator unbiased.

5.3.2.8.4 Improved wind vector error estimates

Previous L2B products for both SeaWinds and QuikSCAT used a bi-quadratic fit to the MLE objective function in the neighborhood of a refined wind vector solution to compute an estimate of the uncertainties in wind speed and direction for the solution. This algorithm, inherited from SeaSat and

NSCAT, provided unreasonably low estimates of the direction errors, and often did not work at all due to artifacts in the shape of the MLE surface. As a result of the revamping of the retrieval solution search code (described above), the old algorithm was abandoned.

A new algorithm, based on the 2dimensional integration of the probability distribution around each wind vector solution, has been developed and incorporated into the wind retrieval code. The algorithm uses the full set of directional probabilities instead of intervals to compute error bars on the ambiguities. The errors in the ambiguity selection method and DIRTH are not modeled. Each error bar is a conditional error estimate given that the corresponding ambiguity is the correct one.

We make use of the MLE objective function f values and best speed values computed as a function of wind direction during wind retrieval. If we assume that the noise on the various Sigma0 measurements is mutually independent Gaussian noise, then one can show that the probability of a given wind speed and direction pair, $p(\phi, u)$ is proportional to $\exp(-f(\phi, u)/2)$. If we had MLE estimates for the entire speed and direction space we could then compute the expected RMS direction error and speed error directly by the following two integrals:

$$\int_{\phi \in N_i} \int_u p(u, \phi) \angle(\phi, \phi_i)^2 du d\phi$$

$$\int_{\phi \in N_i} \int_u p(u, \phi) (u - u_i)^2 du d\phi$$

$$p(u, \phi) = k \exp(-f(u, \phi)/2)$$

where i is the index of the ambiguity and N_i is the set of directions closest to the i th ambiguity, and the $\angle(\phi, \phi_i)$ function denotes “angular difference”. The proportionality coefficient k is computed so that

$$\int_{\phi \in N_i} \int_u p(\phi, u) du d\phi = 1$$

This condition is the same as assuming the i th ambiguity is the closest to the true direction (i.e., the probability of any direction which is closer to one of the other ambiguities is zero).

Since we only have MLE values in the near proximity of the best speed ridge, we cannot perform the full integration. Instead we integrate along the best speed ridge and assume the MLE values are quadratic in speed for constant direction. We checked these assumptions by performing the full 2-D integration for a single SeaWinds L2B file and comparing the error bars obtained with the approximate computation. We found very good agreement with low biases and RMS approximation errors. See [Stiles4] for details.

5.3.2.8.5 Multi-pass ambiguity removal and mixed-surface WVC's

A “multi-pass” version of the median filter ambiguity removal algorithm was employed previously in the SeaWinds L2B processing to reduce the effects of rain-impacted wind vector cells on nearby neighbors. The algorithm excluded rainy WVCs from the initial iterative pass of the median filter to first make selections in the “clear” WVCs, freeze those selections in the second pass to influence the selections in the rain-flagged cells, and then do a final pass to improve the overall consistency of the selections. In the process of considering both high-resolution wind retrievals and attempting to retrieve winds closer to the coast, we also wished to minimize the propagation of potentially land-contaminated wind vectors into the open ocean selections. In the augmented multi-pass median filter, we have expanded to a fourth pass and leave the selection of vectors in the “coastal” and “ice” flagged WVC's (those cells with sufficient ocean sigma0s for wind retrieval, but which contain some land or ice sigma0s not used in the retrieval) until the last pass. The algorithm as now implemented follows the following scheme:

PASS 1: Exclude “coastal” and “ice” WVC as well as rain from first median filtering pass.

PASS 2: “Freeze” the non-rain, non-coastal WVC selections, continue masking the coastal WVC, and filter the rain-flagged WVC.

PASS 3: Refilter all rain and non-rain WVC selections to achieve better mutual consistency, while still masking the coastal WVC.

PASS 4: Freeze the non-coastal selections, and filter the coastal WVC. Note that we do not refilter all of the data after this pass in order to keep coastal selections from propagating into the open ocean.

5.3.2.9 Other Algorithm Improvements

5.3.2.9.1 SRad brightness temperature recalibration and rain rate estimation

The SRad rain rate estimation algorithm which was included in the previous (2003) SeaWinds L2B products has been updated by K. Ahmed and L. Jones (OVWST meeting, March 2005) and the improved algorithm has been implemented in the current SeaWinds L2B processor.

The improved SRad rain rate depends on a recalibration of the SRad ocean brightness temperatures to more closely match those of QuikSCAT. The recalibration is applied in the L2A processing as a tabular correction to the SRad Tb calculated in the L1B data. The table is a function of polarization (H, V), along-track orbital position, and time (by month). The corrections were derived by histogram matching of the SRad Tb to corresponding QRad Tb data. The corrections are described and plotted in support package [SRad]. The recalibration enables us to use the same rain rate algorithm for both SeaWinds and QuikSCAT. In addition the SRad recalibration forces the SeaWinds Tb, which are used in the IMUDH autonomous rain flag algorithm as input parameters, to have the same bulk statistical behavior as the QuikSCAT QRad, facilitating the transfer of the IMUDH algorithm from SeaWinds to QuikSCAT.

The rain rate algorithm itself is based on a calibration of SRad excess brightness temperature (i.e. after removal of a climatological mean background T_b) versus TMI rain rates. A 3×3 weighted filter is applied to the Tex for each polarization to smooth the data and reduce noise inherent in the SRad T_b prior to application of the calibration. The details of the algorithm were presented at the OVWST meeting in Seattle (March 2005) and are provided in support package [SRad] along with some sample results.

5.3.2.9.2 Land flag based on high-resolution land-sea map

We have adopted a new high-resolution (2 arc-minute) land-sea map for use in σ_0 land-flagging. Land flags are set according to where the center of the σ_0 cell falls on the land-sea map. To account for the spatial extent of the SeaWinds σ_0 footprint we “expand” the coastlines radially outward by a given distance. Previous QuikSCAT and SeaWinds land flags used a map with a 30km coastal expansion for 25km “egg” σ_0 and winds. This has been adopted also for the current 25km SeaWinds L2A/L2B processing using the new map. For the 12.5km L2B data we have used a 20km mask based on the analysis described below:

The OVWST has expressed a significant interest in retrieval of winds closer to the coast than 30km. The ability to do this depends on the extent to which the σ_0 are contaminated by land, either from the antenna side lobes or from partial land coverage. Since the Ku-band σ_0 of land and ice is significantly different and generally higher than the ocean return, and the variance of the σ_0 over land is very low, it should be relatively easy to identify and flag the land-contaminated measurements. To test just how close to the coast we can retrieve good winds with SeaWinds, we generated a version of the high-resolution land map with a series of coast expansion factors [0,5,10,15,20,25,30,35]km and looked at the histograms of “land” and “ocean” σ_0 s within each 5km band (0-5km, 5-10km, ...) away from the coast. The land flag algorithm was modified to use any two of these masks to define a “coastal zone”. Any σ_0 that is flagged differently by the inner and outer masks is identified as falling into this zone; a beam-dependent σ_0 threshold is then applied, and σ_0 values above this threshold are flagged as land. The danger of applying such a threshold to the σ_0 is that true high winds may be flagged as land. Note that the algorithm reverts to the original geometric algorithm, without a σ_0 threshold, if the same mask is selected for both the inner and outer masks.

We applied the two-mask algorithm using an inner mask at 10km and outer mask at 15km, with σ_0 thresholds of -14.5 dB on both beams, for a full-mission run of the 12.5km SeaWinds L2B. The results are better than using only the 10km mask for flagging, but still show significant elevation of mean wind speed around the coastlines of islands and continents. The tendency for land contamination in the 12.5km data has been shown to be dependent on the relative orientation of σ_0 slices to the nearby coastline; slices that are nearly parallel to the coast do not show significant contamination, while slices more perpendicular to the coast are definitely contaminated. This is due to the fact that the σ_0 slices are only about 5km wide in the range direction (radially away from the instrument) but are about 25km wide in the azimuth direction. For this reason we have used the more conservative 20km mask, without thresholding, for the 12.5km L2B data.

5.3.3 Level 3 Processing

Each SeaWinds Level 3 data file contains one day or less of SeaWinds data. A complete day includes data from all Level 2B wind vector cells (WVCs) whose row time matches the observation date. Level 2B data are rev based. A rev begins and ends at the southernmost orbital latitude, and constitutes one complete revolution of SeaWinds around Earth. The Level 3 Product further divides a rev into ascending and descending phases. Data acquired when the spacecraft is moving in a Northerly direction are in the ascending phase. Data acquired when the spacecraft is moving in a Southerly direction are in the descending phase.

The SeaWinds Level 3 Processor reads SeaWinds Level 2B wind speeds and directions, and generates the Level 3 Product. The SeaWinds Level 3 Processor groups Level 2B WVCs by their location into a rectangular latitude/longitude grid of cells which span the entire globe. Each grid cell is 1/4 degree on each side. Furthermore, the Level 3 Processor separates the ascending and descending phases of orbit into separate grids.

Occasionally, two or more Level 2B WVCs will be located in the same Level 3 grid cell. In the case where the Level 2B WVCs come from different revs, data from the later rev overwrite data from a previous rev. In the case where the Level 2B WVCs come from the same rev, data from the Level 2B WVC which is closest to the center of the Level 3 grid cell are used. Thus, there is no averaging of quantities in Level 3 grid cells.

In addition to wind speeds and directions, the Level 3 Product also grids attenuation correction, time, rain probability, and rain flagging data from the Level 2B Product.

The Level 3 Processor may use wind speed and direction data from one of the following three different sources in the Level 2B Product:

1. Wind speeds and directions based on the Direction Interval Retrieval (DIR) algorithm.
2. Wind speeds and directions based on the selected ambiguity.
3. Wind speeds and directions based on the first ambiguity.

Under nominal conditions, the Level 3 Processor uses wind speeds and directions based on the Direction Interval Retrieval (DIR) algorithm. The metadata element `wind_vector_source` indicates the source of the Level 2B wind vector data that is used for a particular Level 3 Product.

6 Geophysical Data Product Content & Format

SeaWinds science data consists of the following data products:

Level 3 Data – Daily, Gridded Ocean Wind Vectors

Level 2B Data – Ocean Wind Vectors in 25 and 12.5 km Swath Grid

Level 2A Data – Surface Flagged Sigma0s and Attenuations in 25 and 12.5 km Swath Grid

Level 1B Data – Time-Ordered Earth-Located Sigma0s

This section presents an overview of the level data product information detailed in the Software Interface Specification (SIS) documents. (See Section 1.3 of this document for references.) The SIS documents should be consulted if more detailed information about the data products is required.

The products described herein, are presented in the order of expected use by most data users. The last subsection for each level data product presents important notes on data usage.

6.1 SeaWinds Level 3 Product – Daily, Gridded Ocean Wind Vectors

The SeaWinds on SeaWinds Level 3 data set consists of gridded values of scalar wind speed, meridional and zonal components of wind velocity and time given in fraction of a day. Rain probability determined using the Impact Multidimensional Histogram (IMUDH) Rain Flagging technique is also included as an indicator of wind values that may have degraded accuracy due to the presence of rain.

The Level 3 data were obtained from the Direction Interval Retrieval with Threshold Nudging (DIRTH) wind vector solutions contained in the SeaWinds Level 2B data and are provided on an approximately $0.25^\circ \times 0.25^\circ$ global grid. Separate maps are provided for both the ascending pass (10:30PM LST equator crossing) and descending pass (10:30AM LST equator crossing). By maintaining the data at nearly the original Level 2B sampling resolution and separating the ascending and descending passes, very little overlap occurs in one day. However, when overlap between subsequent swaths does occur, the values are over-written, not averaged. Therefore, a SeaWinds on ADEOS II Level 3 file contains only the latest measurement for each day.

This product is also referred to as JPL PO.DAAC product 142.

6.1.1 Level 3 Header

The contents of the SeaWinds Level 3 header are metadata. The header data set covers the entire contents of the file. A set of HDF global attributes stores the entire Level 3 header. The name of each

global attribute used for metadata storage matches the name of the metadata element. Each global attribute consists of ASCII characters and contains at least three lines of data. The information specified in each global attribute indicates the data type, the array size and contents of the metadata element.

A sizable subset of the metadata elements is defined by the ECS. In the ECS environment, most of these elements are mandatory. In general, these elements specify critical information with regard to the accompanying data granule. The ECS utilizes these metadata elements to identify and to locate particular data granules within their system.

The remaining metadata elements describe the contents of the file, or list important constants, which apply to the entire data set within the file.

6.1.1.1 Level 3 Header Structure

The following table lists all of the elements in the SeaWinds Level 3 header. The table specifies the maximum number of entries for each header element. Each metadata element is stored in an HDF global attribute. Section 7.6 describes the format of metadata.

The name of the global attribute is the same as the name of the metadata element that the global attribute stores. Words within ECS metadata element names are capitalized and are not separated by any characters or spaces. SeaWinds metadata element names are all in lower case and words are separated by underscore characters or by capitalized letters.

Table 6.1 Header Structure for L3 Product

Element Name	Maximum Array Size
LongName	[1]
ShortName	[1]
producer_agency	[1]
producer_institution	[1]
InstrumentShortName	[1]
PlatformLongName	[1]
PlatformShortName	[1]
PlatformType	[1]
projected	[1]
data_format_type	[1]
GranulePointer	[1]
QAGranulePointer	[1]
InputPointer	[16]
ancillary_data_descriptors	[5]
sis_id	[1]
build_id	[1]
HDF_version_id	[1]
ParameterName	[1]
QAPercentOutOfBoundsData	[1]
QAPercentMissingData	[1]
ProductionDateTime	[1]

wind_vector_source	[1]
wind_vector_cell_resolution	[1]
observation_date	[1]
num_13_rows	[1]
num_13_columns	[1]
13_actual_grid_cells	[1]
13_actual_grid_cells_asc	[1]
13_actual_grid_cells_dsc	[1]
13_algorithm_descriptor	[8]
OperationMode	[1]
RangeBeginningDate	[1]
RangeEndingDate	[1]
RangeBeginningTime	[1]
RangeEndingTime	[1]
percent_rev_data_usage	[16]
OrbitParametersPointer	[32]
EquatorCrossingLongitude	[16]
EquatorCrossingTime	[16]
EquatorCrossingDate	[16]
StartOrbitNumber	[1]
StopOrbitNumber	[1]

6.1.2 Level 3 Data

Each data element represents a unique HDF SDS object. The name of each Level 3 HDF object is the same as the name of the data element that the HDF object stores.

Every SDS object is an array of three dimensions. In every case, the first array index specifies the grid cell row, the second array index specifies a grid cell column in that row, and the third index specifies an orbital phase. A value of 0 for the third index indicates the ascending phase of the orbit while a value of 1 indicates the descending phase of the orbit.

For example, data elements rep_wind_speed[16,200,0] and rep_wind_velocity_u[16,200,0] reference the same grid cell in the same orbital phase.

6.1.3 Level 3 Data Structure

Table 6.1.2 Level 3 Data Structure

Element Name	Conceptual Type	Storage Type	Repetition	Scale	Minimum	Maximum
rep_wind_speed	real	uint16	[720,1440,2]	0.01	0.00	50.00
rep_wind_velocity_u	real	int16	[720,1440,2]	0.01	-50.00	50.00
rep_wind_velocity_v	real	int16	[720,1440,2]	0.01	-50.00	50.00
rep_atten_corr	real	int16	[720,1440,2]	0.001	0.000	32.767

rep_time_of_day	real	uint16	[720,1440,2]	0.0001	0.0000	0.9999
rep_rain_probability	real	uint16	[720,1440,2]	0.001	0.000	1.000
rep_srad_rain_rate	real	int16	[720,1440,2]	0.01	0.00	50.00
rep_amsr_rain_indicator	real	int16	[720,1440,2]	0.01	-20.00	100.00
rain_flag	integer	uint8	[720,1440,2]	1	0	1
null_data_indicator	integer	uint8	[720,1440,2]	1	0	1

6.1.4 Level 3 Bit Flag Conventions

At the start of Level 3 processing, all SeaWinds bit flag values are initialized. The standard procedure for SeaWinds initialization of bit flags sets all defined bits to 1 and all undefined bits to 0. If the Level 3 Processor detects an anomalous condition, which halts the processing for a particular grid cell, the appropriate bit flag, which indicates the error condition remains set to 1. Since the processor may curtail subsequent operations for the grid cell that failed the test, those bit flags, which normally would be tested in subsequent code, also retain their initialized value. Thus, the order in which bit flags are processed determines whether their values are meaningful.

For instance, if `grid_cell_quality_flag` indicates that no wind vector data are available for a particular Level 3 grid cell, the Level 3 Processor does not clear bit 0 for that cell. Thus, the bits which represent Multiple Wind Vector Cells (bit 1) and Data Overwritten (bit 2) remain set to 1. These settings are not indicative of the conditions for the Level 3 grid cell. Users should ignore these values. Similarly, none of the other bits in `grid_cell_quality_flag` contain useful data if bit 0 is set to 1.

The following table lists the `grid_cell_quality_flag` bit flag dependencies. The column on the left lists the pivotal flags. The middle column lists the two possible values for a flag. The column on the right indicates the effect of that flag's value on other bits in `grid_cell_quality_flag`.

Table 6.1.3 Bit Flag Dependencies

Bit Flag	Value	Effect on Other Bits
Data Exists Flag (bit 0)	0	All other bits are meaningful
	1	None of the other bits are meaningful
Multiple WVC Flag (bit 1)	0	Data Overwritten Flag (bit 2) is not meaningful
	1	Data Overwritten Flag (bit 2) is meaningful
Rain Flag Usable (bit 3)	0	Rain Flag (bit 4) is meaningful
	1	Rain Flag (bit 4) is not meaningful
Attenuation Correction Flag (bit 6)	0	Attenuation Source Flag (bits 7 and 8) is meaningful
	1	Attenuation Source Flag (bits 7 and 8) is not meaningful

6.1.5 Level 3 Null Values

SeaWinds null values are listed as zeros in the Level 3 Product. The Level 3 Product does, however, contain adequate information so that users can easily distinguish null values from actual zero values.

The Level 3 Product contains null values whenever a grid cell is empty. A grid cell is empty if the `null_data_indicator` is set to 1 for that cell. This flag distinguishes null values from zero values for certain SDS objects. If the `null_data_indicator` specifies that wind vector data does not exist for a particular Level 3 grid cell, then the listed zero values for that cell are null values.

In those situations, the Level 3 Product lists zeros for all of the data elements associated with that grid cell except for `null_data_indicator` and `grid_cell_quality_flag`. These zero values should be interpreted as null values.

For example, if the `rep_wind_speed` value for the grid cell at array location [210,34,0] is equal to zero, and `null_data_indicator` is equal to 0, then `rep_wind_speed[210,34,0]` contains a true zero value. If, on the other hand, `null_data_indicator` is equal to 1, then `rep_wind_speed[210,34,0]` contains a null value.

The SDS objects for `rep_wind_velocity_u`, `rep_wind_velocity_v`, `rep_atten_corr`, `rep_time_of_day`, `rep_rain_probability`, and `rain_indicator` should be interpreted similarly.

The Data Exists Flag (bit 0) in `grid_cell_quality_flag` works identically to `null_data_indicator` and may also be used to check for null values. Only `null_data_indicator` or bit 0 of `grid_cell_quality_flag` needs to be checked, not both.

6.2 SeaWinds Level 2B Product—Ocean Wind Vectors in 25 and 12.5-km Swath Grid

The Level 2B product consists of ocean wind vector solutions organized by full orbital revolution of the spacecraft or 'rev'. Each Level 2B file represents one satellite rev.

6.2.1 SWS/AMSR L2B product (25km only)

The SeaWinds/AMSR Level 2B products contain wind retrievals from `sigma0` data corrected with the AMSR empirical corrections for attenuation and atmospheric backscatter. These products also contain the estimated rain impact values, in both speed and direction, based on the AMSR corrections that were applied. The MUDH rain flag bits in the `WVC_quality_flag` have been replaced with flags indicating the validity of the rain impact values and whether or not the estimated impacts exceed the selected threshold values of 2m/s or 15 degrees. Approximately 1.8% of the data on average has the rain impact flag set. Note that the impact flag in this product does not indicate that the data is necessarily bad; the `sigma0` corrections and resulting wind vectors appear to be robust for over 99% of the data. The user wishing to exclude flagged data should look not only at the impact flag, but also at whether or not the speed and direction rain impacts are at extreme values (well above the flagging threshold).

6.2.2 SWS-only L2B products (25km and 12.5km)

The SeaWinds scatterometer-only Level 2B products have the same content and format as the previous release in October 2003. The wind retrievals in these products are based on sigma0 data corrected with the SSM/I attenuation climatology that has been used on NSCAT, QuikSCAT, and SeaWinds in previous and current data. All of the wind retrieval enhancements, variance corrections, and improvements to the SRad rain rate estimate are included in the scatterometer-only data. The IMUDH rain flag algorithm, trained against the rain impact of the SWS/AMSR L2B, is used to set the rain flags in these products. Please note that the IMUDH flags from the 25km products are used to flag the 12.5km wind vector cells.

We are releasing the SWS-only products at both 25km and 12.5km resolution. The contents of the data at both resolutions are the same. The 12.5km processing is based on slice-composite sigma0 to achieve the higher resolution. In the slice-composite processing the sigma0s are composed of one or more contiguous slices, from the same pulse, for which the centers of the slices fall into the WVC. From our analysis of the L2A 12.5km products we have found that about 43% of the sigma0s are composed of a single 5km x 25km slice, 38% are 2-slice composites, 18% have 3 slices, and less than 1% are 4-slice composites.

6.2.3 Level 2B Header

The contents of the SeaWinds Level 2B header are contained in metadata elements, which are stored as HDF global attributes. The header data covers the entire contents of the file.

The name of each global attribute used for metadata storage matches the name of a metadata element. Each global attribute consists of ASCII characters and contains at least three lines of data. The information specified in each global attribute indicates the data type, the array size and contents of the metadata element.

6.2.4 Level 2B Header Structure

The following table lists all of the elements in the SeaWinds Level 2B header. All of the header elements except skip_start_time and skip_stop_time must appear in every Level 2B Product file. These two optional elements delimit data gaps or regions of data that were not processed. These metadata elements appear only when sequences of data were missing from Level 2A data which were used to generate the Level 2B Product.

Table 6.2.1 Header Structure for L2B Product

Element Name	Definition	Max Array Size
LongName	“SeaWinds Level 2B Ocean Wind Vectors in 25 [12.5] km Swath Grid”	[1]
ShortName	“SWSL2B”	[1]
producer_agency	“NASA”	[1]
producer_institution	“JPL”	[1]

InstrumentShortName	“SeaWinds”	[1]
PlatformLongName	“Advanced Earth Observing Satellite II”	[1]
PlatformShortName	“ADEOS-II”	[1]
PlatformType	“spacecraft”	[1]
project_id	“SeaWinds”	[1]
data_format_type	“NCSA HDF”	[1]
GranulePointer	A pointer to the output data granule	[1]
QAGranulePointer	A pointer to the quality assurance granule.	[1]
InputPointer	A pointer to the major input data granule.	[1]
ancillary_data_descriptors	An array of file names, which specifies all of the ancillary data, files which were used to generate the output product.	[10]
OrbitParametersPointer	A pointer to one data granule or a set of granules that provide the orbit parameters, which are used to generate the data in this product.	[5]
sis_id	A character string that specifies which SIS document describes the organization and format of data in the file.	[1]
build_id	A character string that identifies the version of the SeaPAC software that was used to generate this data file.	[1]
HDF_version_id	A character string, which identifies the version of the HDF software, which was used to generate this data file.	[1]
ParameterName	“wind_speed”	[1]
QAPercentOutOfBoundsData	The percent of instances when a particular data element within the data product is out of bounds.	[1]
QAPercentMissingData	The percent of instances when a particular data element within the data product is missing.	[1]
OperationMode	“Wind Observation”	[1]
StartOrbitNumber	The orbit number, which corresponds to the data at the beginning of the granule.	[1]
StopOrbitNumber	The orbit number, which corresponds to the data at the end of the granule.	[1]
EquatorCrossingLongitude	The interpolated longitude of the equator crossing of the spacecraft nadir track in the ascending direction.	[1]
EquatorCrossingTime	The interpolated time of the equator crossing of the spacecraft nadir track in the ascending direction.	[1]
EquatorCrossingDate	The date of the equator crossing of the spacecraft nadir track in the ascending direction.	[1]
rev_orbit_period	The time between two consecutive ascending node crossings in the spacecraft orbital path.	[1]
orbit_inclination	The angle between the plane of the spacecraft’s orbital path and the earth’s equatorial plane.	[1]
orbit_semi_major_axis	The length of the semimajor axis of the ADEOS-II spacecraft orbit.	[1]
orbit_eccentricity	The eccentricity of the spacecraft orbital path.	[1]
rev_number	The assigned revolution number based on the spacecraft orbital history.	[1]
RangeBeginningDate	The initial date for data coverage within this SeaWinds data product.	[1]
RangeEndingDate	The final date for data coverage within this SeaWinds data product.	[1]
RangeBeginningTime	The initial time for data coverage within this SeaWinds data product	[1]
RangeEndingTime	The final time for data coverage within this SeaWinds data product.	[1]
ProductionDateTime	Wall clock time when this data file was created.	[1]
skip_start_time	A specific date and time which indicates where a nonexistent, unnecessary, spurious, questionable, or erroneous data segment begins.	[10]

skip_stop_time	A specific date and time which indicates where a nonexistent, unnecessary, spurious, questionable, or erroneous data segment ends.	[10]
sigma0_attenuation_method	“Attenuation Map” or “None”	[1]
median_filter_method	“Wind direction median” or “Wind vector median”	[1]
nudging_method	“None” or “NWP Weather Map”	[1]
ephemeris_type	“GPS”, “EPHD” or “EPHP”	[1]
l2b_algorithm_descriptor	A set of character strings which list important details about the implementation of the L2B Processor algorithm that were used to generate this product.	[8]
l2b_actual_wvc_rows	The number of wind vector cell rows.	[1]
l2b_expected_wvc_rows	The expected number of wind vector cell rows.	[1]
sigma0_granularity	“whole pulses”, “slice composites”, “composites of composites” ,or “pulse slices”	[1]

6.25 Level 2B Data

The Level 2B data are grouped by rows of wind vector cells (WVC). Level 2B wind vector cells are 25 km squares. Each wind vector cell row corresponds to a single cross-track cut of the SeaWinds measurement swath. Full coverage of the earth’s circumference requires *nrow* wind vector cell rows.

The SeaWinds instrument’s measurement swath extends 900 km on either side of the satellite nadir track. Thus, each WVC row must contain at least 72 WVC values. To accommodate occasional measurements that lie outside of the 900 km swath, the Level 2B data design includes two additional WVC values at each end of each row. Each Level 2B WVC row therefore contains a total 76 (or 152 for the 12.5 km product) WVCs.

Except for the *wvc_row_time*, an HDF SDS object stores every data element in the Level 2B Data. An HDF Vdata object stores the *wvc_row_time*. The number of *wvc_row_time* entries matches the number of WVC rows in the Level 2B Product.

Except for the element *wvc_row*, every SDS is an array of at least two dimensions. The first SDS dimension represents the WVC row while the second dimension represents a particular WVC within the row.

The Level 2B Product numbers the wind vector cells from left to right when viewing the orbital swath in the direction of spacecraft flight. Thus, *num_ambigs*[203,15] lists the number of retrieved ambiguities for the 16th wind vector cell from the left hand side of the swath when facing the spacecraft’s forward direction of motion in *wvc_row*[203].

Several of the Level 2B SDS objects are three-dimensional arrays. For all of these SDS objects, the third array index represents a potential wind solution.

Each WVC includes up to four potential wind velocity solutions. These potential solutions are called ‘ambiguities’. The SDS objects *wind_speed*, *wind_dir*, *wind_speed_err*, *wind_dir_err* and *max_likelihood_est* list these ambiguities in descending likelihood order. Therefore, the value stored in *wind_speed*[210,34,0] is the wind speed solution with the greatest likelihood estimator for the wind vector cell stored at array location[210,34]. Likewise, if an entry exists in location

wind_speed[210,34,3], its value represents the wind speed solution with the smallest likelihood estimator for the same WVC. The SDS object wvc_selection indicates which of the ambiguities was selected by the median filter ambiguity removal algorithm.

The DIR (Direction Interval Retrieval) algorithm enhances the solution selected by ambiguity removal. When the Level 2B Processor uses DIR, the metadata element l2b_algorithm_descriptor in the Level 2B Product indicates that the wind direction of the selected ambiguity has been enhanced.

When DIR is in use, the SDS objects wind_speed_selection and wind_dir_selection list the output from DIR processing. Users who have interest in the wind solution based on DIR should employ the data that are stored in these SDS objects. Users who are interested in wind solutions that have not been modified by the DIR algorithm should locate the data element that represents the selected ambiguity in the SDS objects wind_speed and wind_dir. For instance, if wvc_selection[204,30] indicates that the second ambiguity was selected, then the solutions that were not enhanced by DIR processing are located in data elements wind_speed[204,30,1] and wind_dir[204,30,1].

When the Level 2B Processor does not use the DIR algorithm, the SDS objects wind_speed_selection and wind_dir_selection list the wind speed vector that was selected by ambiguity removal. Thus, if DIR is not in use, and data element wvc_selection[612,54] indicates that the first ambiguity was selected, wind_speed_selection is then equal to wind_speed[612,54,0], and wind_dir_selection is equal to wind_dir[612,54,0].

6.26 Level 2B Data Structure

Figures illustrating the internal structure of the SeaWinds Level 2B data can be found in Section 3.2 of the [Level 2B Data Software Interface Specification \(SIS\)](#).

Except for the wvc_row_time, each entry in this table represents a unique HDF SDS object. The wvc_row_time is stored in an HDF Vdata object. The name of each Level 2B HDF object is the same as the name of the data element that the HDF object stores.

With the exception of wvc_row, every SDS object is an array of at least two dimensions. In every case, the first array index specifies the wind vector cell row while the second array index specifies a wind vector cell in that row. For all three-dimensional SDS elements in the Level 2B Product, the third dimension represents one of the wind solution ambiguities.

For example, data elements wvc_row[256] and wvc_row_time[256] reference the same wind vector cell row. Data elements wvc_lon[256,12] and num_ambigs[256,12] represent the same wind vector cell. Data elements wind_dir[256,12,1] and wind_speed[256,12,1] represent the same ambiguity in the same wind vector cell.

The following table lists each element in the Level 2B Data. For the 25 km product, [nrow,ncol] = [1624,76], and for the 12.5 km product [nrow,ncol] = [3248,152].

Table 6.2 Data Structure for L2B Product

Element Name	Storage Type	Repetition	Scale	Minimum	Maximum
wvc_row_time	char	[nrow]	n/a	1993-001 T00: 00: 00.000	2008-366 T23: 59: 60.999
wvc_row	int16	[nrow]	1	1	nrow
wvc_lat	int16	[nrow,ncol]	0.01	-90.00	90.00
wvc_lon	uint16	[nrow,ncol]	0.01	0.00	359.99
wvc_index	int8	[nrow,ncol]	1	1	ncol
num_in_fore	int8	[nrow,ncol]	1	0	127
num_in_aft	int8	[nrow,ncol]	1	0	127
num_out_fore	int8	[nrow,ncol]	1	0	127
num_out_aft	int8	[nrow,ncol]	1	0	127
wvc_quality_flag	uint16	[nrow,ncol]	1	0x0000	0x7F83
atten_corr	int16	[nrow,ncol]	0.001	0	32.767
model_speed	int16	[nrow,ncol]	0.01	0.00	70.00
model_dir	uint16	[nrow,ncol]	0.01	0.00	359.99
num_ambigs	int8	[nrow,ncol]	1	0	4
wind_speed	int16	[nrow,ncol,4]	0.01	0.00	50.00
wind_dir	uint16	[nrow,ncol,4]	0.01	0.00	359.99
wind_speed_err	int16	[nrow,ncol,4]	0.01	0.00	50.00
wind_dir_err	int16	[nrow,ncol,4]	0.01	0.00	180.00
max_likelihood_est	int16	[nrow,ncol]	0.001	-30.0	0.0
wvc_selection	int8	[nrow,ncol]	1	0	4
wind_speed_selection	int16	[nrow,ncol]	0.01	0.00	50.0
wind_dir_selection	uint16	[nrow,ncol]	0.01	0.00	359.99
mp_rain_probability	int16	[nrow,ncol]	0.001	-3.000	1.000
nof_rain_index	uint8	[nrow,ncol]	1	0	250
amsr_rain_indicator	int16	[nrow,ncol]	0.01	-20.00	100.00
srاد_rain_rate	int16	[nrow,ncol]	0.01	0.00	50.00
rain_impact_speed	int16	[nrow,ncol]	0.01	0.00	50.00
rain_impact_dir	int16	[nrow,ncol]	0.01	0.00	359.99

Items in red are new to this release for SWS/AMSR L2B Data Structure only.

6.2.7 Level 2B Bit Flag Convention

At the start of processing, all SeaWinds bit flag values are initialized. The standard procedure for SeaWinds initialization of bit flags sets all defined bits to 1 and all undefined bits to 0. If the Level 2B Processor detects an anomalous condition which halts the processing for a particular wind vector cell, the appropriate bit flag which indicates the error condition remains set to 1. Since the processor may curtail subsequent operations for the wind vector cell that failed the test, those bit flags that normally would be tested in subsequent code also retain their initialized value. Thus, the order in which bit flags are processed determines whether their values are meaningful.

For instance, if `wvc_quality_flag` indicates that there is poor azimuth diversity among the σ_0 values in a wind vector cell, the Level 2B Processor does not retrieve winds for that cell. Since wind retrieval does not take place, the code cannot determine whether wind solutions for that wind vector cell are within or outside of the optimal range. Thus, the bits which represent the presence of either high and low wind speeds in the wind vector cell remain set to 1. These settings indicate neither a high nor a low wind speed. Users should ignore these values. On the other hand, the remaining bits in the `wvc_quality_flag` do contain valid values. These bits are valid, because they were determined before the Level 2B Processor halted processing for the associated wind vector cell.

The following table lists the `wvc_quality_flag` bit flag dependencies. The column on the left lists the pivotal Wind Retrieval Flag. The middle column lists the two possible values for that bit. The column on the right indicates which of the remaining bits in the `wvc_quality_flag` are meaningful under the specified conditions.

Table 6.3 Wvc_Quality_Flag Bit Flag Dependencies

Bit Flag	Value	Other Bits with Meaningful Value
Wind Retrieval Flag (bit 9)	0	Adequate Sigma0 Flag (bit 0)
		Adequate Azimuth Diversity Flag (bit 1)
		Attenuation Method Data Flag (bit 2)
		Available AMSR Attenuation Flag (bits 3 and 4)
		AMSR Weather Condition Flag (bits 5 and 6)
		Coastal Flag (bit 7)
		Ice Edge Flag (bit 8)
		High Wind Speed Flag (bit 10)
		Low Wind Speed Flag (bit 11)
		IMUDH Rain Flag Usable (bit 12)
		Available Data Flag (bit 14)
		AMSR Rain Indicator Flag (bit 15)
		1
	Adequate Azimuth Diversity Flag (bit 1)	
	Attenuation Method Data Flag (bit 2)	
	Available AMSR Attenuation Flag (bits 3 and 4)	
	AMSR Weather Condition Flag (bits 5 and 6)	
	Coastal Flag (bit 7)	
	Ice Edge Flag (bit 8)	
	IMUDH Rain Flag Usable (bit 12)	
AMSR Rain Indicator Flag (bit 15)		

The `wvc_quality_flag` contains two other pairs of bit flags that have pivotal relationships. The value of the Available AMSR Attenuation Flag (bits 3 and 4) impacts the meaning of the AMSR Weather Condition Flag (bits 5 and 6). If the Available AMSR Attenuation Flag indicates that no AMSR attenuation measures were available for any of the sigma0s in a wind vector cell, the processor can not ascertain a value for the ASMR Weather Condition Flag. Thus, the bits that represent the AMSR Weather Condition Flag remain set to 1. These values do not imply that heavy rain was detected.

Likewise, bit 12, which indicates whether the Impact Multidimensional Histogram (IMUDH) rain flag is usable, impacts the value of the Multidimensional Histogram (MUDH) Algorithm Rain Flag (bit 13). If bit 12 indicates that the IMUDH Rain Flag is unusable, the value of IMUDH Algorithm Rain Flag remains set to 1. That value does not indicate that the IMUDH algorithm detected rain.

6.28 Level 2B Null Values

SeaWinds null values are listed as zeros in the Level 2B Product. The Level 2B Product does, however, contain adequate information so that users can easily distinguish null values from actual zero values.

The Level 2B Product contains null values whenever a wind vector cell has fewer than four ambiguities. In those situations, the Level 2B Product lists zeros for all of the data elements associated with each unneeded ambiguity in that wind vector cell. Clearly, these zero values should be interpreted as null values.

For example, if all the `wind_dir` values for the WVC at array location [210,34] are equal to zero, and `num_ambigs` is equal to 3, then the `wind_dir[210,34,0]`, `wind_dir[210,34,1]` and `wind_dir[210,34,2]` are true zero values. On the other hand, `wind_dir[210,34,3]` is a null value. The SDS objects for `wind_speed`, `wind_speed_err`, `wind_dir_err` and `max_likelihood_est` should be interpreted similarly.

The wind retrieval flag in the `wvc_quality_flag` distinguishes null values from zero values for certain SDS objects. If the `wvc_quality_flag` indicates that wind retrieval did not take place, then the listed zero values for `model_speed`, `model_dir`, `num_ambigs`, `wind_speed`, `wind_dir`, `wind_speed_err`, `wind_dir_err`, `max_likelihood_est` and `wvc_selection` are null values.

6.29 Rain Flagging Techniques

The SeaWinds scatterometer was developed by NASA JPL to accurately measure the normalized radar cross section (σ_0) of the ocean surface. Such measurements are then used to infer the speed and direction of ocean surface winds. When rain is present, measurements of the ocean surface σ_0 become contaminated for several reasons. Some of the transmitted energy is scattered back towards the scatterometer by the rain and never reaches the ocean surface. Energy backscattered from rain can constitute a significant but unknown portion of the measured echo energy. Some of the transmitted energy is scattered and/or absorbed by the rain and is never measured by the scatterometer. This has the effect of attenuating the echo energy from the ocean. Additionally, the rain roughens the ocean surface and changes its radar cross section.

Two rain-flagging scientific data sets, `mp_rain_probability` and `nof_rain_index`, are included to indicate the detection of rain contamination in the SeaWinds Level 2B data, in addition to the `amsr_rain_indicator`. Please note that the `nof_rain_index` is incorporated as an additional parameter in the IMUDH rain algorithm (`mp_rain_probability`).

6.2.9.1 mp_rain_probability

mp_rain_probability is derived using the Impact Multidimensional Histogram (IMUDH) Rain-Flagging Technique developed by James Huddleston and Bryan Stiles at NASA JPL. For a detailed description of the MUDH technique, please refer to the “Multidimensional Histogram (MUDH) Rain Flag Product Description” [Huddleston and Stiles, 2000].

Briefly, mp_rain_probability is the probability of encountering a columnar rain rate that is greater than 2 km*mm/hr. This probability value is read directly from a table based on eight input parameters including nof_rain_index and the average brightness temperature. The space spanned by these parameters can detect whether the set of σ_o used in wind retrieval contain a noteworthy component created by some physical phenomenon other than wind over the ocean’s surface.

Values of mp_rain_probability range between 0 and 1. Missing values are indicated by a value of -3.0. Additionally, bit 12 of the wvc_quality_flag indicates whether the MP algorithm computation was valid (0) or invalid (1), and bit 13 indicates whether rain was detected (1) or not detected (0) by the algorithm. Bit 14 of the wvc_quality_flag indicates whether the rain detection is based on data from both beams (0) or from outer-beam measurements only (1).

6.2.9.2 nof_rain_index

nof_rain_index is derived using the Normalized Objective Function (NOF) Rain-Flagging Technique developed by Carl Mears, Frank Wentz and Deborah Smith at Remote Sensing Systems. For a detailed description of the NOF technique, please refer to the “SeaWinds on SeaWinds Normalized Objective Function Rain Flag Product Description” [Mears et al, 1999].

nof_rain_index is based upon a simplified version of the standard model function to determine a maximum likelihood estimator and a wind speed for each wind vector cell. The maximum likelihood estimator is based upon the sum of the squared differences between the set of σ_o that were used to retrieve winds and the corresponding model function σ_o that would generate the ambiguity with the greatest maximum likelihood estimator. The wind speed is based upon a modified σ_o , which is specifically calculated to be less sensitive to rain. The simplified maximum likelihood estimator is normalized by a tabular empirical estimate for the 95th percentile of the squared difference distribution. These tabular values are indexed by beam polarization, cross track location in the measurement swath and wind speed. The normalized maximum likelihood estimator is then divided by the number of σ_o ’s in the wind vector cell, multiplied by thirty, and rounded to the nearest integer value.

nof_rain_index is most effective for wind speeds under 10 m/s and should not very effective for wind speeds greater than 15 m/s. Users should employ this flag with caution in regions of high wind speed.

Values of nof_rain_index range between 0 and 249. Invalid values are indicated with a nof_rain_index of 250.

6.2.10 Level 2B Data Usage Notes

The L2B data set is the most highly processed standard product and has the simplest flagging.

wvc_qual_flag (See: L2B SIS, Sect. 3.5.68): This flag will be 0 for the best data. The key bit is bit 9 indicating that wind retrieval was performed. A value of 1 for bit 9 indicates that no wind retrieval was performed, and therefore no ambiguities were calculated (variable “num_ambigs”=0) nor was any ambiguity chosen by an ambiguity removal algorithm (“wvc_selection”=0).

The coastal (bit 7) or ice edge (bit 8) flags will be of interest to investigators attempting to work close to land or ice; these advisory bits may be set if any part of the wind vector cell was over land or ice, respectively, even though sufficient good ocean σ_0 measurements were available in the WVC to retrieve winds.

While accuracy requirements do not apply outside the 3 to 30 m/s range indicated by the high (bit 10) and low (bit 11) speed flags, and preliminary analysis shows that these winds have larger differences from NWP models, there is nothing inherently wrong with winds with the speed flags set. It is, however, suggested that winds below 1 m/s be used with great caution. In addition, as is well known, the model function has had less development and previous correlative validation measurements are rare above about 20 m/s.

Rain flagging bits: Bit 12 indicates whether the rain flag bit 13 is usable. Thus, when bit 12 is set to 0 and bit 13 set to 1, rain is indicated. When both bits 12 and 13 are set to 0, no rain is indicated.

Data availability: Bit 14 indicates whether all four instrument “views” (inner and outer beams looking fore and aft of the spacecraft) were available; this will always be 1 (invalid) in the outer swath as only the outer beam (V-pol) is available.

wvc_selection (L2B SIS 3.5.71): The variables “wind_speed” and “wind_dir” contain speed and direction information for up to four ambiguities for each wind vector cell. As noted in the SIS and Users Guide, the ambiguities are listed in decreasing likelihood order. The variable “wvc_selection,” if non-zero, contains a pointer (values 1 to 4) to the ambiguity selected by the ambiguity removal algorithm. Therefore, the first-listed ambiguity in “wind_speed” and “wind_dir” does not correspond automatically to the chosen ambiguity. Cells with wvc_selection=0 have no ambiguity selected and should be excluded from comparisons and most statistics.

The L2B data set also contains nudge field wind speed (“model_speed”) and wind direction (“model_dir”) estimates for each valid wind vector cell. These speed and direction values are derived from the available operational NCEP global 2.5° resolution, 1000mb analysis closest in time to the SeaWinds overpass at the geographical location of the WVC. They represent spatially, but not temporally, interpolated winds. Wind speeds are estimates for the 1000 mb level – they are not 10 m wind speeds. Comparisons between the SeaWinds wind velocity estimates and the “model” wind velocity estimates contained in the L2B data provide only an exceptionally crude indication of the accuracy of the SeaWinds winds.

The “atten_corr” variable in the L2B product contains a single, representative value for the atmospheric attenuation in each WVC. The actual attenuation corrections applied to each backscatter measurement in a WVC (from a monthly average map) prior to wind retrieval can be different from the

single `atten_corr` value. Please refer to Section 9.6.1 for a more complete listing of Level 2B flag values.

6.3 SeaWinds Level 2A Product—Surface Flagged Sigma0s and Attenuations in 25 and 12.5 km Swath Grid

The Level 2A product consists of σ_0 values for every radar backscatter measurement acquired during one satellite rev. Each σ_0 is based on the sum of the echo energies measured among the eight center high resolution slices in a single scatterometer pulse. The Level 2A Product file also contains ancillary data elements that correspond to each of the σ_0 values. Among the ancillary data elements are entries that list the location, the quality and the uncertainty of the σ_0 values.

6.3.1 SWS Level 2A with AMSR-derived corrections (25km and 12.5km)

The SWS Level 2A products have been augmented since the October 2003 release to include AMSR-derived corrections (previously left empty), and add new data (physical model atmospheric backscatter and attenuation per path length, empirical model attenuation and atmospheric backscatter). This augmentation has allowed us to use the L2A data as input to three distinct L2B processing schemes, two with AMSR-based corrections (physical and empirical) and one using the attenuation climatology for the scatterometer-only L2B. The scatterometer sigma0 data is in the same format as in the previous release; the AMSR corrections and WVC quadrant flags are in the WVC quadrant format. The “amsr_pointer” array, which holds a value for each sigma0 for the 12.5km WVC quadrant index, allows matching up the AMSR corrections with the sigma0 data for the physical corrections. The empirical model attenuation and backscatter are in 1:1 correspondence with the sigma0 data, and are based on the AMSR SST, water vapor, and total liquid at the WVC quadrant resolution from the AMSR L1B.

Please note that for the 12.5km L2A data, we have made no attempt to validate, nor do we guarantee, the quality of the AMSR-based corrections. The decision to produce the 12.5km L2A and L2B data was made late in this process. The 12.5km L2A products have been generated solely as inputs to the scatterometer-only 12.5km L2B products, which use the attenuation climatology. Some amount of redesign of the product and processor for 12.5km is in order; if the AMSR geophysical data and corrections are output at the 12.5km WVCs, rather than in 6.25km quadrants, this would save on data volume for the 12.5km L2A and allow for the possibility of producing a 12.5km L2B/AMSR product in the future.

6.3.2 Level 2A Header

The contents of the SeaWinds Level 2A header are contained in metadata elements, which are stored as HDF global attributes. The header data covers the entire contents of the file.

The name of each global attribute used for metadata storage matches the name of a metadata element. Each global attribute consists of ASCII characters and contains at least three lines of data. The

information specified in each global attribute indicates the data type, the array size and value of the metadata element.

6.3.3 Level 2A Header Structure

The following table lists all of the elements in the SeaWinds Level 2A Header. All of the header elements except skip_start_time and skip_stop_time must appear in every Level 2A Product file. These two optional elements delimit data gaps or regions of data that were not processed. These metadata elements appear only when expected sequences of data are missing from the Product file.

Table 6.4 Header Structure for L2A Product

Element Name	Definition	Max Array Size
LongName	“SeaWinds Level 2A Surface Flagged Sigma0s and Attenuations in 25 km Swath Grid”	[1]
ShortName	“SWSL2A”	[1]
producer_agency	“NASA”	[1]
producer_institution	“JPL”	[1]
InstrumentShortName	“SeaWinds”	[1]
PlatformLongName	“Advanced Earth Observing Satellite II”	[1]
PlatformShortName	“ADEOS-II”	[1]
PlatformType	“spacecraft”	[1]
project_id	“SeaWinds”	[1]
data_format_type	“NCSA HDF”	[1]
GranulePointer	A pointer to the output data granule	[1]
QAGranulePointer	A pointer to the quality assurance granule.	[1]
InputPointer	A pointer to the major input data granule.	[1]
ancillary_data_descriptors	An array of file names, which specifies all of the ancillary data, files which were used to generate the output product.	[10]
OrbitParametersPointer	A pointer to one data granule or a set of granules that provide the orbit parameters that are used to generate the data in this product.	[5]
sis_id	A character string that specifies which SIS document describes the organization and format of data in the file.	[1]
build_id	A character string that identifies the version of the SeaPAC software that was used to generate this data file.	[1]
HDF_version_id	A character string that identifies the version of the HDF software that was used to generate this data file.	[1]
ParameterName	“wind_speed”	[1]
QAPercentOutOfBoundsData	The percent of instances when a particular data element within the data product is out of bounds.	[1]
QAPercentMissingData	The percent of instances when a particular data element within the data product is missing.	[1]
OperationMode	“Wind Observation”	[1]
StartOrbitNumber	The orbit number that corresponds to the data at the beginning of the granule.	[1]
StopOrbitNumber	The orbit number that corresponds to the data at the end of the granule.	[1]
EquatorCrossingLongitude	The interpolated longitude of the equator crossing of the spacecraft nadir track in the	[1]

	ascending direction.	
EquatorCrossingTime	The interpolated time of the equator crossing of the spacecraft nadir track in the ascending direction.	[1]
EquatorCrossingDate	The date of the equator crossing of the spacecraft nadir track in the ascending direction.	[1]
rev_orbit_period	The time between two consecutive ascending node crossings in the spacecraft orbital path.	[1]
orbit_inclination	The angle between the plane of the spacecraft's orbital path and the earth's equatorial plane.	[1]
orbit_semi_major_axis	The length of the semi-major axis of the ADEOS-II spacecraft orbit.	[1]
orbit_eccentricity	The eccentricity of the spacecraft orbital path.	[1]
rev_number	The assigned revolution number based on the spacecraft orbital history.	[1]
RangeBeginningDate	The initial date for data coverage within this SeaWinds data product.	[1]
RangeEndingDate	The final date for data coverage within this SeaWinds data product.	[1]
RangeBeginningTime	The initial time for data coverage within this SeaWinds data product	[1]
RangeEndingTime	The final time for data coverage within this SeaWinds data product.	[1]
ProductionDateTime	Wall clock time when this data file was created.	[1]
skip_start_time	A specific date and time, which indicates where a nonexistent, unnecessary, spurious, questionable, or erroneous data segment begins.	[10]
skip_stop_time	A specific date and time, which indicates where a nonexistent, unnecessary, spurious, questionable, or erroneous data segment ends.	[10]
maximum_sigma0s_per_row	The maximum number of composite sigma0 measurements among all of the wind vector cell rows in the accompanying SeaWinds level product file.	[1]
ephemeris_type	"GPS", "EPHD" or "EPHP"	[1]
l2a_algorithm_descriptor	A set of character strings that list important details about the implementation of the L2A Processor algorithm that was used to generate this product.	[8]
l2a_actual_wvc_rows	The number of wind vector cell rows in the Level 2A Product which contain valid sigma0 measurement data.	[1]
l2a_expected_wvc_rows	The expected number of wind vector cell rows.	[1]
amsr_collocated_wvc_rows	The number of wind vector cell rows within the Level 2A product that contain a significant number of AMSR observations.	[1]
sigma0_granularity	"whole pulses", "slice composites", "composites of composites", or "pulse slices"	[1]
OperationMode	The SeaPAC system does not run the Level 2A Processor unless some Wind Observation mode data are found in the input Level 1B data granule. Thus, the value of OperationMode for all Level 2A Product files should be 'Wind Observation'.	[1]

6.3.4 Level 2A Data

The standard SeaWinds Level 2A Product contains whole pulse σ_0 's. Each whole pulse σ_0 incorporates the measures of the ten center high resolution slices from the same scatterometer pulse. The Level 2A σ_0 's are grouped by wind vector cell (WVC) rows. Each WVC row corresponds to a single cross-track cut of the SeaWinds instrument measurement swath. Each Level 2A WVC is a 25 km square. Thus, n row WVC rows are required to cover one complete circumference of the earth.

The Level 2A Processor passes the full set of data which lie within the input Level 1B Product into the output Level 2A Product. The Level 1B Product is in temporal order and therefore defined by time boundaries. The Level 2A Product is in spatial order and defined by spatial boundaries. To insure that

all data are transferred from the input to the output product, the Level 2A Processor design must consider the data acquisition pattern of the SeaWinds instrument's rotating antenna. As the spacecraft approaches and passes a rev boundary, the SeaWinds instrument acquires data on either side of that boundary. Thus, the Level 2A Product must include wind vector cell rows that extend beyond the row, which comprise one complete earth circumference. To cover those σ_0 measurements that lie beyond the spatial boundaries of the rev, the Level 2A Product includes 39 additional wind vector cell rows before the start and after the end of each rev. These additional wind vector cell rows cover 975 km at each end of the rev. Thus, the nominal Level 2A Product contains a total of 1702 wind vector cell rows.

The nominal instrument measurement swath extends for 900 km to either side of the satellite nadir track. Thus, a total of 72 WVC values, with 36 on either side of the nadir track, should accommodate nearly every σ_0 measurement. The attitude of the ADEOS-II spacecraft and the shape of the earth influence the ultimate location of each backscatter footprint on the earth's surface. Due to these variations, some σ_0 cells fall outside of the nominal 900 km SeaWinds instrument measurement swath. Few if any composite σ_0 cells, however, should lie further than 950 km from the spacecraft nadir track. Thus, the Level 2A Product design includes four additional cell indices per WVC row. The Level 2A data entry cell_index stores the location indicator for each composite σ_0 within the WVC row.

Since the SeaWinds pencil beam antenna rotates as the spacecraft travels, the number of composite σ_0 measurements that fall within each particular WVC is highly dependent on the cell's cross-track location. Studies indicate that a few cells located about 700 km from spacecraft nadir track may contain 40 or more scatterometer pulses. Most cells in the swath, however, are likely to contain between 12 and 30 scatterometer pulses. Clearly, a data design that assigns adequate space for the maximum number of expected pulses to every WVC in the grid is wasteful.

Using the spacecraft velocity and the instrument telemetry pulse rate, a simple calculation determines the expected number of measurement pulses, which the SeaWinds instrument can acquire over its full swath as it travels between two along-track locations. At the nominal pulse rate of 187.5 Hertz, the SeaWinds instrument pulses approximately 709 times, as the spacecraft travels a distance of 25 km. This distance is the width of one Level 2A WVC row.

The Level 2A data design takes advantage of this constant pattern. The Level 2A Product groups composite σ_0 cells by WVC row.

Space should be available in the Level 2A Product to accommodate the number of measurements acquired when the Scatterometer Electronic Subsystem pulses at the nominal rate. Using the nominal rate, approximately 709 whole pulse measurements should appear in each wind vector cell row. To insure that no σ_0 s are lost, the SeaWinds software allocates adequate space for 810 σ_0 in each wind vector cell row.

The Level 2A Product also includes data that are based on collocated and contemporaneous observations that were acquired from the Advanced Microwave Scanning Radiometer (AMSR). The Level 2A Product does not list the individual AMSR observations. Instead, the Level 2A

Product divides each wind vector cell into four quadrants, and lists representative measures based on the AMSR observations for every wind vector cell quadrant in the rev.

The wind vector cell rows provide a common basis for grouping all of the data elements within the Level 2A Data. The Level 2A Data are divided into three major subsets, each of which are based on finer grouping criteria. These subsets are the Wind Vector Cell Row Header, the Wind Vector Cell Sigma0 Data and the Wind Vector Cell Quadrant AMSR Data.

Figures illustrating the internal structure of the SeaWinds Level 2A data can be found in Section 3.2 of the [Level 2A Data Software Interface Specification \(SIS\)](#).

6.3.5 Level 2A Data Structure

6.3.4.1 Level 2A Wind Vector Cell Row Header

The Wind Vector Cell Row Header contains three data elements that apply to every sigma0 in a wind vector cell row and seven data elements that apply to every sigma0 in each of the wind vector cells within that row. With one exception, all of the elements in the Wind Vector Cell Row Header are stored in an HDF SDS data object. The name of each SDS object matches the data element that it stores.

The one exception is `wvc_row_time`, which is stored in an HDF Vdata object. `wvc_row_time` is a one dimensional array. Each element in `wvc_row_time` is representative of an entire wind vector cell row.

Among the SDS objects in the Wind Vector Cell Row Header, only `row_number` and `num_sigma0` are one dimensional arrays. Like `wvc_row_time`, each element in both of these arrays is representative of an entire wind vector cell row.

All of the remaining entries in the Wind Vector Cell Row Header are two dimensional SDS objects. For each of these data elements, the first array index represents the wind vector cell row. The second array index represents one of the wind vector cells within the row. SeaWinds products number wind vector cells from left to right when viewing the orbital swath in the direction of spacecraft flight.

Thus, `num_sigma0_per_cell[390,70]` contains the number of sigma0 entries in the 71st wind vector cell from the left hand side of the swath when facing the direction of spacecraft flight in the 391st wind vector cell row.

The following table lists the data elements in the Wind Vector Cell Row Header:

Table 6.5: Wind Vector Cell Row Header

Element Name	Conceptual Type	Storage Type	Repetition	Scale	Minimum	Maximum
wvc_row_time	time	char	[nrow]	n/a	1993-001T00:00:00.000	2016-366T23:59:60.999
row_number	integer	int!6	[nrow]	1	1	nrow
num_sigma0	integer	int!6	[nrow]	1	0	nsig
num_sigma0_per_cell	unsigned integer	uint8	[nrow,ncol]	1	0	80
num_wvc_tb_in	unsigned integer	uint8	[nrow,ncol]	1	0	40
num_wvc_tb_out	unsigned integer	uint8	[nrow,ncol]	1	0	40
mean_wvc_tb_in	real	uint16	[nrow,ncol]	0.01	0	350
mean_wvc_tb_out	real	uint16	[nrow,ncol]	0.01	0	350
std_dev_wvc_tb_in	real	uint16	[nrow,ncol]	0.01	0	350
std_dev_wvc_tb_out	real	uint16	[nrow,ncol]	0.01	0	350

6.3.4.2 Wind Vector Cell Sigma0 Data

The Wind Vector Cell Sigma0 Data include all of the measures that correspond to each individual sigma0. Each element in the Wind Vector Cell Sigma0 Data is stored in a separate SDS object. The name of each SDS object matches the data element that it stores.

All of the objects in the Wind Vector Cell Sigma0 Data are two dimensional. The first dimension index specifies the wind vector cell row, while the second dimension index represents the sigma0.

Thus, `cell_azimuth[379,42]` and `cell_incidence[379,42]` are the azimuth and incidence angles for the 43rd sigma0 measurement in the 380th wind vector cell row.

Data element `cell_index` identifies the particular wind vector cell within the row where the sigma0 is located. Sea-Winds products number wind vector cells from left to right when viewing the orbital swath in the direction of spacecraft flight. Thus, if `cell_index[379,42]=2`, then the 43rd sigma0 in the 380th wind vector cell row is located within the 2nd wind vector cell.

The following table lists the data elements in the Wind Vector Cell Sigma0 Data. For the 25 km product, [nrow,ncol,nsig] = [1702,76,810], and for the 12.5 km product [nrow,ncol,nsig] = [3404,152,2000].

Table 6.6: Wind Vector Cell Sigma0 Data

Element Name	Conceptual Type	Storage Type	Repetition	Scale	Minimum	Maximum
cell_lat	real	int16	[nrow,nsig]	0.01	-90.00	90.00
cell_lon	real	uint16	[nrow,nsig]	0.01	0.00	359.99
cell_azimuth	real	uint16	[nrow,nsig]	0.01	0.00	359.99
cell_incidence	real	int16	[nrow,nsig]	0.01	40.00	60.00
sigma0	real	int16	[nrow,nsig]	0.01	-300.00	20.00
kp_alpha	real	int16	[nrow,nsig]	0.001	0.100	2.000
kp_beta	real	uint16	[nrow,nsig]	1.0E-7	1.0E-6	1.0E-3
kp_gamma	real	float32	[nrow,nsig]	1.0	1.0E-10	1.0E-2
sigma0_qual_flag	enum	uint16	[nrow,nsig]	1	0x0000	0x0BFF
sigma0_mode_flag	enum	uint16	[nrow,nsig]	1	0x0000	0x1FFE
surface_flag	enum	uint16	[nrow,nsig]	1	0x0000	0x0FSF
cell_index	unsigned integer	uint8	[nrow,nsig]	1	0	ncol
sigma0_attn_map	real	int16	[nrow,nsig]	0.01	-50.00	30.00
amsr_pointer	unsigned integer	uint8	[nrow,nsig]	1	0	4
empirical_atm_att.	real	int16	[nrow,nsig]	0.01	0.	100.
empirical_atm_backscatter	real	int16	[nrow,nsig]	0.01	0.	100.

Items in red are new to this release

6.3.4.3 Wind Vector Cell Quadrant AMSR Data

The Wind Vector Cell Quadrant AMSR Data contain measurements and quality metrics that are based on observations from the Advanced Microwave Scanning Radiometer (AMSR). A set of four 12.5 km wind vector cell quadrants occupies each of the 25 km wind vector cells that the Level 2A Product uses to classify the location of sigma0s.

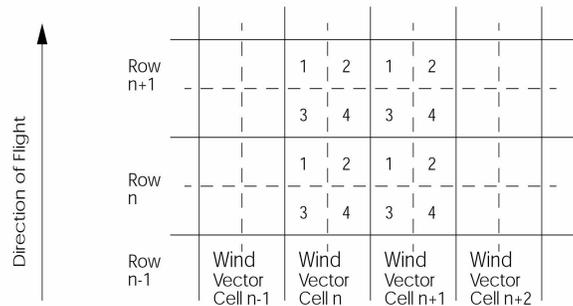
Each element in the Wind Vector Cell Quadrant AMSR Data is stored in a unique SDS object. The name of each SDS object matches the data element that it stores.

Each data object in the Wind Vector Cell Quadrant AMSR Data is a three dimensional array. The first dimension index specifies the wind vector cell row. The second dimension index represents the wind vector cell within the row. The third dimension index represents one of the four 12.5 km AMSR quadrants within each wind vector cell. The following table describes the index convention for the quadrants within each wind vector cell when viewing the orbital swath in the direction of spacecraft flight:

Third Dimension Index	Cell Location
0	left and forward
1	right and forward
2	left and aft
3	right and aft

Thus, `amsr_atm_attn[379,42,2]` is the representative atmospheric attenuation of scatterometer backscatter measure for any σ_0 that is located in the left aft corner of the 43rd wind vector cell in the 380th wind vector cell row.

The following figure displays the relative arrangement of the wind vector cells in the spacecraft swath, and the location of the wind vector cell quadrants within them:



The following table lists the data elements in the Wind Vector Cell Quadrant AMSR Data:

Table 6.7: Wind Vector Cell Quadrant AMSR Data

Element Name	Conceptual Type	Storage Type	Repetition	Scale	Minimum	Maximum
amsr_atm_attn	real	int16	[nrow,ncol,4]	0.01	-50.00	100.00
amsr_atm_backscatter	real	int16	[nrow,ncol,4]	0.01	-50.00	150.00
amsr_atm_attn_uncert	real	int16	[nrow,ncol,4]	0.01	0.00	10.00
amsr_atm_backscatter_uncert	real	int16	[nrow,ncol,4]	0.01	0.00	10.00
wvc_quad_rain_indicator	real	int16	[nrow,ncol,4]	0.01	-20.00	100.00
wvc_quad_qual_flag	enum	uint32	[nrow,ncol,4]	n/a	0x00000000	0x000FFFFF
amsr_dist_to_quad_center	integer	int16	[nrow,ncol,4]	1	0	9000

6.3.6 Level 2A Bit Flag Convention

At the start of processing, all SeaWinds bit flag values are initialized. The standard procedure for SeaWinds initialization of bit flags sets all defined bits to 1 and all undefined bits to 0. When the Level 2A Processor notes the successful completion of any logical step that is recorded in the bit flags, the processor clears the corresponding bit flag to 0. On the other hand, if the processor should detect an anomalous condition that halts the processing for a particular σ_0 , the appropriate bit flag that indicates the error condition remains set to 1. Since the processor may curtail subsequent operations for any σ_0 that fails a test, those bit flag conditions, which normally would be tested in the subsequent code, could retain their initialized value. Thus, the order in which bit flags are processed often determines whether their values are meaningful.

For instance, if the surface_flag for a particular composite σ_0 indicates that land is present, the Level 2A Processor does not test whether ice is present. Since the code does not test for ice, the value of the surface ice flag and ice map available flag remain set to 1. Clearly, these values for the surface ice flag and the ice map available flag are not indicative of the conditions for that σ_0 .

On the other hand, the Level 2A Processor does attempt to calculate attenuation for every σ_0 regardless of whether the measurement had been flagged for land or for ice. Thus, the value of the attenuation map available flag is always correct, regardless of previously flagged conditions.

The Level 2A Processor handles the AMSR based data separately from the sigma0s. Thus, the validity of the bit flags that indicate conditions based on AMSR data do not depend on the surface_flag bits that record the progress of sigma0 processing. On the other hand, the AMSR based bit flags can be meaningful if and only if usable AMSR data are available for the associated sigma0. Thus, if the surface_flag indicates that usable AMSR data are not available for a selected sigma0, then none of the bits in the surface_flag that record conditions based on AMSR data are meaningful.

The following table describes the bit flag dependencies for the surface_flag in the Level 2A Product. The column on the left lists three pivotal bits in the surface_flag. The middle column lists the possible values for those bits. The column on the right indicates which of the remaining bits in the surface_flag are meaningful under the corresponding conditions.

Table 6.8 Surface_Flag Bit Flag Dependencies

Bit Flag	Value	Other Bits with Meaningful Value	
Surface land flag (bit 0)	0	Ice map data available flag (bit 10)	
		Attenuation map data available flag (bit 11)	
		Usable AMSR data available flag (bit 9)	
	1	Attenuation map data available flag (bit 11)	
Surface ice flag determined by map (bit 1)	0	Surface land flag (bit 0)	
		Ice map data available flag (bit 10)	
		Attenuation map data available flag (bit 11)	
		1	Surface land flag (bit 0)
	Attenuation map data available flag (bit 11)		
	Usable AMSR data available flag (bit 9)		
Ice map data available flag (bit 10)	0	Surface land flag (bit 0)	
		Surface ice flag determined by map (bit 1)	
		Attenuation map data available flag (bit 11)	
		Usable AMSR data available flag (bit 9)	
		1	Surface land flag (bit 0)
	Attenuation map data available flag (bit 11)		
		Usable AMSR data available flag (bit 9)	
Usable AMSR data available flag (bit 9)	0	All other flags based on AMSR data (bits 2,3,7,8). Flags based on sigma0 data if the dependencies for the surface land flag (bit 0), the surface ice flag based on land map (bit 1) and the ice map data available flag (bit 10) are met.	
	1	Flags based on sigma0 data if the dependencies for the surface land flag (bit 0), the surface ice flag based on land map (bit 1) and the ice map data available flag (bit 10) are met.	

6.3.7 Level2A Null Values

SeaWinds null values are listed as zeros in the Level 2A Product. The Level 2A Product does, however, contain adequate information so that users can easily distinguish null values from actual zeros.

The Level 2A Product lists null values whenever the maximum number of sigma0s in a wind vector cell row is less than the maximum 810. As an example, assume the SDS num_sigma0 indicates that there are 700 sigma0 records in a particular wind vector cell row. For that wind vector cell row, each SDS contains exactly 700 valid second dimension entries. The Level 2A Product lists zeros for every data element that represents a sigma0 with a second dimension index which is greater than or equal to 700 for that wind vector cell row. Clearly, all of those zeros should be interpreted as null values.

Based on this example, assume that num_sigma0[400] is 700. If cell_lat[400,699] and cell_lat[400,700] are both equal to zero, cell_lat[400,699] is a true zero value. The associated sigma0 is located on the equator. On the other hand, cell_lat[400,700] is a null value. This data interpretation method applies to all of the data objects in the Level 2A Product where the second dimension index references a sigma0.

The data element cell_index verifies the existence of null entries. Every sigma0 must lie within a wind vector cell. Thus, if the cell_index for a particular pair of indices is zero, no associated sigma0 exists. In other words, if cell_index[400,700]=0, then the index pair [400,700] lists null values for all of Level 2A Product data elements that reference individual sigma0s.

The attenuation map available bit in the surface_flag also distinguishes zero from null values in the Level 2A Product. If the surface_flag indicates that attenuation data based on the climatological map are not available, then the sigma0_attn_map data element with matching array indices is zero. That zero represents a null value.

The AMSR data availability bit in the wvc_quad_qual_flag distinguishes zeros from null values for any of the data elements that are stored in the 12.5 km wind vector cell quadrants. If the wvc_quad_qual_flag indicates that AMSR data are not available, then all of the elements in the Wind Vector Cell Quadrant AMSR Data with matching array indices are zero. All of these zeros represent null values.

6.3.8 Level 2A Data Usage Notes

sigma0_qual_flag (See: L2A SIS, Sect. 3.5.60): This is the key flag for σ_0 quality. Note the dependencies table in the SIS. For good data it will = 0, except, perhaps, for the negative σ_0 flag in bit 2. Because of the noise subtraction process, it is possible to obtain an estimate of signal power that is < 0 giving a negative σ_0 . Since most σ_0 's are fractional, they are represented as negative in dB. Thus to indicate an estimate of negative signal power, bit 2 is set. These are valid measurements from very low backscatter areas (low wind speed, land, etc.) Data with low SNR (third bit) may also be valid, but are of lesser quality.

Please refer to Section 9.6.2 for a more complete listing of Level 2A flag values.

6.4 SeaWinds Level 1B Product—Time-Ordered Earth-Located Sigma0s

Each Level 1B file represents one satellite rev. The Level 1B Product lists the σ_0 and the σ_0 slice values for each radar backscatter measurement within the rev. In addition, the Level 1B Product includes elements which specify the location and the quality of each backscatter measurement. The product contains a few additional parameters that indicate particular conditions and uncertainties that the higher level SeaWinds Processors require.

6.4.1 Level 1B Header

The contents of the SeaWinds Level 1B header are contained in metadata elements, which are stored as HDF global attributes. Each header data set applies to the entire contents of the file.

The name of each global attribute used for metadata storage matches the name of a metadata element. Each global attribute consists of ASCII characters and contains at least three lines of data. The information specified in each global attribute indicates the data type, the array size and contents of the metadata element.

6.4.2 Level 1B Header Structure

The following table lists all of the elements in the SeaWinds Level 1B header. All of the header elements except skip_start_time, skip_stop_time, skip_start_frame and skip_stop frame must appear in every Level 1B Product file. These four optional elements delimit data gaps of regions of data that were not processed. These metadata elements appear only when expected sequences of data are missing from the Product file.

Table 6.9 Header Structure for L1B Product

Element Name	Definition	Max Array Size
LongName	“SeaWinds Level 1B Time-Ordered Earth-Located Sigma0s”	[1]
ShortName	“SWSL1B”	[1]
producer_agency	“NASA”	[1]
producer_institution	“JPL”	[1]
InstrumentShortName	“SeaWinds”	[1]
PlatformLongName	“Advanced Earth Observing Satellite II”	[1]
PlatformShortName	“ADEOS-II”	[1]
PlatformType	“spacecraft”	[1]
project_id	“SeaWinds”	[1]
data_format_type	“NCSA HDF”	[1]
GranulePointer	A pointer to the output data granule	[1]

QAGranulePointer	A pointer to the quality assurance granule.	[1]
InputPointer	A pointer to the major input data granule.	[1]
ancillary_data_descriptors	An array of file names that specifies all of the ancillary data files which were used to generate the output product.	[32]
OrbitParametersPointer	A pointer to one data granule or a set of granules that provide the orbit parameters that are used to generate the data in this product.	[5]
sis_id	A character string that specifies which SIS document describes the organization and format of data in the file.	[1]
build_id	A character string that identifies the version of the SeaPAC software that was used to generate this data file.	[1]
HDF_version_id	A character string that identifies the version of the HDF software that was used to generate this data file.	[1]
ParameterName	“wind_speed”	[1]
QAPercentOutOfBoundsData	The percent of instances when a particular data element within the data product is out of bounds.	[1]
QAPercentMissingData	The percent of instances when a particular data element within the data product is missing.	[1]
OperationMode	“Wind Observation”	[1]
StartOrbitNumber	The orbit number that corresponds to the data at the beginning of the granule.	[1]
StopOrbitNumber	The orbit number that corresponds to the data at the end of the granule.	[1]
EquatorCrossingLongitude	The interpolated longitude of the equator crossing of the spacecraft nadir track in the ascending direction.	[1]
EquatorCrossingTime	The interpolated time of the equator crossing of the spacecraft nadir track in the ascending direction.	[1]
EquatorCrossingDate	The date of the equator crossing of the spacecraft nadir track in the ascending direction.	[1]
rev_orbit_period	The time between two consecutive ascending node crossings in the spacecraft orbital path.	[1]
orbit_inclination	The angle between the plane of the spacecraft’s orbital path and the earth’s equatorial plane.	[1]
orbit_semi_major_axis	The length of the semi-major axis of the ADEOS-II spacecraft orbit.	[1]
orbit_eccentricity	The eccentricity of the spacecraft orbital path.	[1]
rev_number	The assigned revolution number based on the spacecraft orbital history.	[1]
RangeBeginningDate	The initial date for data coverage within this SeaWinds	[1]

	data product.	
RangeEndingDate	The final date for data coverage within this SeaWinds data product.	[1]
RangeBeginningTime	The initial time for data coverage within this SeaWinds data product	[1]
RangeEndingTime	The final time for data coverage within this SeaWinds data product.	[1]
ProductionDateTime	Wall clock time when this data file was created.	[1]
skip_start_time	A specific date and time, which indicates where a nonexistent, unnecessary, spurious, questionable, or erroneous data segment begins.	[10]
skip_stop_time	A specific date and time, which indicates where a nonexistent, unnecessary, spurious, questionable, or erroneous data segment ends.	[10]
11b_expected_frames	The expected number of telemetry frames in the Level 1B Product file. Under nominal operating conditions, this number will be 11362. This outcome results from instrument and product specifications as well as physical constraints. A nominal SeaWinds telemetry frame encompasses 0.53 seconds of instrument measurements. Every SeaWinds Level 1B Product file contains data for one rev. The maximum number of telemetry frames within a single file is restricted by the number of frames acquired over one complete circumnavigation of the Earth. The estimated orbital time of the ADEOS-II spacecraft is very slightly more than 101 minutes. Thus, the expected number of frames should be 11362.	[1]
11b_actual_frames	The number of telemetry frames which are listed in the Level 1B Product.	[1]
11b_algorithm_descriptor	A set of character strings which list important details about the implementation of the Level 1B Processor algorithm that was used to generate this product.	[8]
ephemeris_type	“GPS”, “EPHD”, or “EPHP”	[1]
attitude_type	“Star Tracker”	[1]
maximum_pulses_per_frame	The maximum number of scatterometer pulses among all of the telemetry frames in this SeaWinds level product file.	[1]
cell_kpc_b	A two dimensional array which contains the first order coefficient of an inverse second order polynomial in the signal to noise ratio.	[8,2]
slice_kpc_b	A two dimensional array which contains the first order	[8,2]

	coefficient of an inverse second order polynomial in the signal to noise ratio.	
cell_kpc_c	A two dimensional array which contains the second order coefficient of an inverse second order polynomial in the signal to noise ratio.	[8,2]
slice_kpc_c	A two dimensional array which contains the second order coefficient of an inverse second order polynomial in the signal to noise ratio.	[8,2]
num_slices_per_sigma0	The number of high resolution slices which combine to determine a representative measurement for each complete scatterometer pulse.	[1]
receiver_gain_ratio	The gain ratio of the echo filter frequency response function to the noise filter frequency response function. Nominally, “4.65”.	[1]
skip_start_frame	The array index of a telemetry frame that specifies where a nonexistent, unnecessary, spurious, questionable, or erroneous data segment begins.	[10]
skip_stop_frame	The array index of a telemetry frame that specifies where a nonexistent, unnecessary, spurious, questionable, or erroneous data segment ends.	[10]

6.4.3 Level 1B Data

The SeaWinds Level 1B data are grouped by telemetry frames. Within these telemetry frames, the Level 1B data are divided into three major subsets. These subsets are the Telemetry Frame Header, the Pulse Data and the Slice Data.

The Telemetry Frame Header data report the state of the SeaWinds instrument as well as indicate the spacecraft position, velocity, and attitude. The Telemetry Frame Header data also include algorithmic and instrument parameters, which are common to all σ_0 cells within the same telemetry frame. All of the Telemetry Frame Header data correspond to the time listed in data element frame_time.

The Pulse Data list the outcome of the SeaWinds implementation of the radar equation for each entire scatterometer pulse. This data set includes parameters that locate each pulse’s footprint on the earth’s surface, as well as indicators of each measurement’s quality and uncertainty.

Most of the Slice Data parameters are analogous to those found in the Pulse Data. The Slice Data elements, however, reference the individual σ_0 slices that are generated by the SeaWinds instrument’s high resolution Linear Frequency Modulation Chirp (LFMC) function. The SeaWinds Level 1B Product lists measurements for the eight innermost slices of each σ_0 . The two slices at either end of the σ_0 pulse do not appear in the Level 1B Product.

An HDF Vdata object stores the `frame_time` data element. An HDF SDS object stores all other data element in the Level 1B Product. The first dimension index of every data object within the Level 1B Data references the telemetry frame. Thus, every data element with the same first dimension index relates to the same telemetry frame. Data element `sc_lat[6212]` specifies the spacecraft latitude at `frame_time[6212]`.

The elements in the Pulse and Slice Data contain a second data index. The second index in these arrays references on of the 100 scatterometer pulses in each telemetry frame. Thus, data element `cell_azimuth[6212,41]` represents the azimuth of the σ_0 cell for the forty second scatterometer pulse in the telemetry frame, which begins at `frame_time[6212]`.

Except for the `slice_qual_flag`, the data elements in the Slice Data contain a third data index. The third index in these arrays represents one of the slices in each pulse. By convention, slices are numbered from the one nearest the spacecraft to the one farthest away. Thus, data element `slice_sigma0[6212,41,3]` contains the normalized radar cross section measurement for the fourth nearest slice of the forty second scatterometer pulse in the telemetry frame which begins at `frame_time[6212]`. Data element `slice_qual_flag` folds all of the information about each slice into a single element. Thus, `slice_qual_flag` does not require the third dimension index.

For more information about the SeaWinds scatterometer slice and pulse geometry, refer to Section 5.2.2.

Figures illustrating the internal structure of the SeaWinds Level 1B data can be found in Section 3.2 of the [Level 1B Data Software Interface Specification \(SIS\)](#).

6.4.4 Level 1B Data Structure

6.4.4.1 Telemetry Frame Header

These entries pertain to an entire telemetry frame within the Level 1B data. Data element `frame_time` is stored in an HDF Vdata object. All of the other data elements are stored in one-dimensional HDF SDS objects. The array index for these SDS objects specifies the telemetry frame. The table below lists the HDF objects in the Level 1B frame header.

Table 6.10 Telemetry Frame Header Structure for L1B Product

Element Name	Storage Type	Repetition	Scale	Minimum	Maximum
<code>frame_time</code>	char	[13000]	n/a	1993-001 T00: 00:00.000	2008-366 T23: 59: 60.999
<code>orbit_time</code>	uint32	[13000]	1	0	4294967295
<code>frame_inst_status</code>	uint32	[13000]	1	0x00000000	0x3FFFFFFF
<code>frame_err_status</code>	uint32	[13000]	1	0x00000000	0x01FFFFFF
<code>frame_qual_flag</code>	uint16	[13000]	1	0x0000	0x001F
<code>num_pulses</code>	int8	[13000]	1	0	100
<code>sc_lat</code>	float32	[13000]	1	-90.000	90.000
<code>sc_lon</code>	float32	[13000]	1	0.000	359.999

sc_alt	float32	[13000]	1	700000	900000
x_pos	float32	[13000]	1	-9999999	9999999
y_pos	float32	[13000]	1	-9999999	9999999
z_pos	float32	[13000]	1	-9999999	9999999
x_vel	float32	[13000]	1	-8000.00	8000.00
y_vel	float32	[13000]	1	-8000.00	8000.00
z_vel	float32	[13000]	1	-8000.00	8000.00
roll	int16	[13000]	0.001	-3.000	3.000
pitch	int16	[13000]	0.001	-3.000	3.000
yaw	int16	[13000]	0.001	-3.000	3.000
bandwidth_ratio	int16	[13000]	0.001	0	32.767
x_cal_A	int16	[13000]	0.01	-300.00	300.00
x_cal_B	int16	[13000]	0.01	-300.00	300.00

6.4.4.2 Pulse Data

The Pulse Data list individual values for each radar backscatter measurement. In some instances, the Pulse Data list instrument calibrations instead of measurements. The Calibration/ Measurement Pulse bit flag in data element sigma0_mode_flag specifies whether the corresponding pulse is a calibration or a measurement.

A distinct SDS object stores each data element in the Pulse Data. The name of each SDS object matches the data element that it stores. All of the data elements in the Pulse Data are two-dimensional arrays. The first dimension index specifies the telemetry frame. The second dimension index represents a particular σ_0 measurement. Data elements cell_lon[4367,15] is the cell longitude and snr[4367,15] is the signal to noise ratio for the 16th σ_0 measurement in the 4368th telemetry frame. The table below lists all of the elements within the Pulse Data.

Table 6.11 Pulse Data Structure for L1B Product

Element Name	Storage Type	Repetition	Scale	Minimum	Maximum
cell_lat	float32	[13000,100]	1	-90.00	90.00
cell_lon	float32	[13000,100]	1	0.00	359.99
sigma0_mode_flag	uint16	[13000,100]	1	0x0000	0x1FFE
sigma0_qual_flag	uint16	[13000,100]	1	0x0000	0x03FF
cell_sigma0	int16	[13000,100]	0.01	-300.00	20.00
frequency_shift	int16	[13000,100]	1	-25000	25000
cell_azimuth	uint16	[13000,100]	0.01	0.00	359.99
cell_incidence	int16	[13000,100]	0.01	44.00	60.00
antenna_azimuth	uint16	[13000,100]	0.01	0.00	359.99
cell_snr	int16	[13000,100]	0.01	-30.00	300.00
cell_kpc_a	int16	[13000,100]	0.0001	0.01	0.1
sws_app_tb	int16	[13000,100]	0.1	0.0	350.0

6.4.4.3 Slice Data

The Slice Data reference each of the slices that are generated by the SeaWinds instrument's high-resolution mode Linear Frequency Modulation Chirp (LFMC) function. In some instances, the Slice Data list instrument calibrations instead of measurements. The Calibration/ Measurement Pulse bit flag in data element `sigma0_mode_flag` specifies whether the corresponding pulse is a calibration or a measurement.

A distinct SDS stores each data element in the Slice Data. Except for the `slice_qual_flag`, all of these data elements are three-dimensional arrays. The first dimension index specifies the telemetry frame. The second dimension index represents the σ_0 measurement. The third dimension index represents each of the slices of the σ_0 measurement. Thus, `slice_sigma0[2304,31,4]` is the normalized backscatter measure and `slice_incidence[2304,31,4]` is the beam incidence angle for the 5th slice of the 32nd pulse in the 2305th telemetry frame.

The `slice_qual_flag` is a two dimensional array. The first dimension index represents the telemetry frame. The second dimension index represents a scatterometer the slices within the scatterometer pulse.

The table below lists all of the elements within the Slice Data.

Table 6.12 Slice Data Structure for L1B Product

Element Name	Storage Type	Repetition	Scale	Minimum	Maximum
<code>slice_qual_flag</code>	uint32	[13000,100]	1	0x00000000	0xFFFFFFFF
<code>slice_lat</code>	Int16	[13000,100,8]	0.0001	-3.2768	3.2767
<code>slice_lon</code>	Int16	[13000,100,8]	0.0001	-3.2768	3.2767
<code>slice_sigma0</code>	Int16	[13000,100,8]	0.01	-300.00	20.00
<code>x_factor</code>	Int16	[13000,100,8]	0.01	-300.00	300.00
<code>slice_azimuth</code>	uint16	[13000,100,8]	0.01	0.00	359.99
<code>slice_incidence</code>	Int16	[13000,100,8]	0.01	40.00	60.00
<code>slice_snr</code>	Int16	[13000,100,8]	0.01	-30.00	300.00
<code>slice_kpc_a</code>	Int16	[13000,100,8]	0.0001	0.01	0.1

6.4.5 Level 1B Bit Flag Convention

The Level 1B Product includes two critical bit flags that identify the data elements that have acceptable quality. The two bit flags are the Data Quality Flag (bit 4) in the `frame_qual_flag` and the Sigma0 Usability Flag (bit 0) in the `sigma0_qual_flag`. If the Data Quality Flag in the `frame_qual_flag` is 0, then most, if not all of the data in the corresponding telemetry frame are valid. If the value of the Data Quality Flag in the `frame_qual_flag` is 1, then all of the data in the corresponding telemetry frame are suspect. If the Sigma0 Usability Flag in the `sigma0_qual_flag` is 0, then the data, which pertain to the corresponding whole scatterometer pulse, are valid. The bit flags in the `slice_qual_flag` indicate whether the data that pertain to each individual slice are valid as well. If the Sigma0 Usability Flag in

the `sigma0_qual_flag` is set to 1, then most, if not all of the data associated with the corresponding telemetry pulses are suspect.

At the start of processing, all SeaWinds bit flag values are initialized. The standard procedure for SeaWinds initialization of bit flags sets all defined bits to 1 and all undefined bits to 0. If the Level 1B Processor detects an anomalous condition which halts the processing for a particular σ_o , or σ_o slice, the appropriate bit flag which indicates the error condition remains set to 1. Since the processor curtails subsequent operations for the σ_o or the slice that failed the test, those bit flags that normally would be tested in subsequent code also retain their initialized value. Thus, the order in which bit flags are processed determines whether their values are meaningful.

For example, if the `sigma0_qual_flag` for a particular σ_o indicates an error in the determination of the cell location, the Level 1B Processor curtails all further processing for that σ_o and its component slices. Since further processing does not take place, most of the remaining bits in the `sigma0_qual_flag` and the `slice_qual_flag` associated with that pulse do not list valid values. Only four bits in the `sigma0_qual_flag` contain valid values. One valid bit indicates the quality of the scatterometer pulse, which is used to calculate the σ_o . Two other valid bits indicate the quality of the ephemeris and attitude data, which are used to locate the σ_o . Finally; the bit that specifies σ_o usability indicates that this σ_o is not usable for wind retrieval purposes. This bit flag value is valid.

The following table describes the bit flag dependencies for the `sigma0_qual_flag` and the `slice_qual_flag` in the Level 1B Product. The column on the left lists the pivotal bits in the `sigma0_qual_flag` and the `slice_qual_flag`. The column on the right indicates which of the remaining bits in the `sigma0_qual_flag` and `slice_qual_flag` are meaningful when the bit in the corresponding left hand column has a value of 0.

The order of the bit flags listed in the left hand column parallels the processing order in the Level 1B Processor. Thus, the order of the blocks provides additional information. If a pivotal bit flag has a value of 0, then all of the bit flags listed in the right hand column of the same table block have meaningful values. If a pivotal bit flag has a value of 1, then all of the bit flags listed in both the left and the right hand columns of the previous table block have meaningful values.

For example, assume that data analysis is based on the value of the cell location flag. If the cell location flag for a particular pulse σ_o is 0, then the eight bit flags in the same table block are valid. These include the σ_o measurement usable flag, the low SNR flag, the pulse quality flag, the frequency shift flag, the attitude data flag, the ephemeris data flag, as well as the location and the low SNR flags for each slice. On the other hand, if the cell location flag for a particular pulse is 1, then the five bit flags listed in both columns of the preceding table block are valid. These include the σ_o measurement usable flag, the pulse quality flag, the cell location flag, the attitude data flag, and the ephemeris data flag.

Table 6.13 Bit Flag Dependencies

Pivotal Bit Flag	Other Bit Flags With Meaningful Value when Pivotal Flag is 0
Pulse quality flag (sigma0_qual_flag bit 4)	Sigma0 measurement usable flag (sigma0_qual_flag bit 0)
	Ephemeris data flag (sigma0_qual_flag bit 9)
Ephemeris data flag (sigma0_qual_flag bit 9)	Sigma0 measurement usable flag (sigma0_qual_flag bit 0)
	Pulse quality flag (sigma0_qual_flag bit 4)
	Cell location flag (sigma0_qual_flag bit 5)
	Attitude data flag (sigma0_qual_flag bit 8)
Cell location flag (sigma0_qual_flag bit 5)	Sigma0 measurement usable flag (sigma0_qual_flag bit 0)
	Low SNR flag (sigma0_qual_flag bit 1)
	Pulse quality flag (sigma0_qual_flag bit 4)
	Frequency shift flag (sigma0_qual_flag bit 6)
	Attitude data flag (sigma0_qual_flag bit 8)
	Ephemeris data flag (sigma0_qual_flag bit 9)
	Center location flag for each slice (slice_qual_flag bits 3, 7, 11, 15, 19, 23, 27, 31)
	Low SNR flag for each slice (slice_qual_flag bits 2, 6, 10, 14, 18, 22, 26, 30)
Frequency shift flag (sigma0_qual_flag bit 6)	Sigma0 measurement usable flag (sigma0_qual_flag bit 0)
	Low SNR flag (sigma0_qual_flag bit 1)
	Negative sigma0 flag (sigma0_qual flag bit 2)
	Sigma0 out of range flag (sigma0_qual_flag bit 3)
	Pulse quality flag (sigma0_qual_flag bit 4)
	Cell location flag (sigma0_qual_flag bit 5)
	Temperature range flag (sigma0_qual_flag bit 7)
	Attitude data flag (sigma0_qual_flag bit 8)
	Ephemeris data flag (sigma0_qual_flag bit 9)
	Center location flag for each slice (slice_qual_flag bits 3, 7, 11, 15, 19, 23, 27, 31)
	Low SNR flag for each slice (slice_qual_flag bits 2, 6, 10, 14, 18, 22, 26, 30)
	Peak gain flag for each slice (slice_qual_flag bits 0, 4, 8, 12, 16, 20, 24, 28)
	Center location flag for slice (slice_qual_flag bits 3, 7, 11, 15, 19, 23, 27, 31)
Negative sigma0 flag for corresponding slice (slice_qual_flag bits 1, 5, 9, 13, 17, 21, 25, 29)	

The Level 1B Processor sets the values of the sigma0_mode_flag before algorithmic processing begins. Thus, the values of the sigma0_mode_flag are valid for all σ_0 in the Level 1B Product.

6.4.6 Level 1B Null Values

SeaWinds null values are listed as zeroes in the Level 1B Product. The Level 1B Product does, however, contain adequate information so that users can distinguish null values from actual zeroes.

Data element `num_pulses` in the Level 1B Product specifies the number of pulses in each telemetry frame. Under normal circumstances, this number should always be 100. When the Level 1B Processor does not process a telemetry frame, the value of `num_pulses` is zero. Thus, when `num_pulses` is zero, virtually all of the other elements in the telemetry frame are zero as well. These zeros represent null values.

If data values associated with a pulse create untenable algorithmic conditions, the Level 1B Processor may curtail processing for that pulse. When these conditions take place, the Level 1B Product displays whatever values the Processor was able to calculate.

The Sigma0 Measurement Usable Flag in the `sigma0_qual_flag` indicates whether the algorithmic process was successful for each pulse. Whenever the Sigma0 Measurement Usable Flag is set, some or all of the values associated with that pulse may be bad or unreliable. When zeros appear in the data elements which represent a pulse where the Sigma0 Measurement Usable Flag is set, the Level 1B Processor most likely did not reach the point in the algorithm where that particular element is calculated. Thus, users should interpret zeros associated with “unusable” σ_0 values as null values.

6.4.7 Level 1B Data Usage Notes

The Level 1B Processor sets the values of the `sigma0_mode_flag` before algorithmic processing begins. Thus, the values of the `sigma0_mode_flag` are valid for all σ_0 values in the Level 1B product.

`frame_err_status` (See: L1B SIS, Sect. 3.5.20): It is recommended that only frames with this flag=0 be used. Other settings indicate unusual instrument conditions, or bad attitude (bit 23), or bad ephemeris (bit 24).

`frame_inst_status` (See: L1B SIS, Sect. 3.5.21): This flag gives information on the instrument state. Many of these bits will normally be non-zero. Normal wind observation mode data will have bits 0-3 = 0000, bits 4-5 = 011, resolution = 6 km, effective gate width 0.5 msec, bit 7 = 0, and bit 8 = variable, bits 9-31 = 0 for the initial configuration and no unusual events in the frame.

`frame_qual_flag` (See: L1B SIS, Sect. 3.5.22): For good telemetry this flag will be 0. If bit 0 or 1 are set the pulses up to the point of filler are probably valid if no other flags indicate otherwise. It is recommended that frames with bit 4 = 1 (bad data found in frame) not be used.

`sigma0_mode_flag` (See L1B SIS, Sect. 3.5.67): This flag gives information on each σ_0 . It propagates some of the information from `frame_inst_status` to individual σ_0 values. Many of the bits will normally be non-zero.

`sigma0_qual_flag` (See: L1B SIS, Sect. 3.5.68): This is the key flag for σ_0 quality. Note the dependencies table in the SIS. For good data it will =0, except, perhaps, for the negative σ_0 flag in bit

2. Because of the noise subtraction process, it is possible to obtain an estimate of signal power, which is < 0 giving a negative σ_0 . Since most σ_0 values are fractional, they are represented as negative in dB. Thus to indicate an estimate of negative signal power, bit 2 is set. These are valid measurements from very low backscatter areas (low wind speed, land, etc.) Data with low SNR (third bit) may also be valid, but are of lesser quality.

slice_qual_flag (See: L1B SIS, Sect. 3.5.81): Four bits give information about each of the 8 slices in a pulse. Except for the second of each set of bits—the negative σ_0 flag—the bits should all be 0 for good data. Data with low SNR (third bit) may also be valid, but are of lesser quality. Note the dependencies table in the SIS.

Please refer to Section 9.6.3 for a more complete listing of Level 1B flag values.



7 Software and Data Conventions

7.1 File Names

SeaWinds data file names are 23 characters in length. The file naming convention is as follows:

Level 1B: SW_S1Bnnnnn.yyyydddhhmm

Level 2A: SW_S2Annnnn.yyyydddhhmm

Level 2B: SW_S2Bnnnnn.yyyydddhhmm

Level 3: SW_S3_aaaadoy.yyydddhhmm

where:

nnnnn:	The ADEOS-II satellite orbital rev number
yyyy:	The calendar year when this product was generated
ddd:	The day of the year when this product was generated
aaaa:	The year measurements were taken.
doy:	The day-of-year measurements were taken..
hh:	The hour in twenty-four hour time when this product was generated
mm:	The minute when this product was generated

7.1.1 Data Product Addition/Changes

In this section we briefly note the changes that have been made to the level data products to create this release.

All of the new products generated in the SeaWinds beta release have augmented filenames. To distinguish the SWS/AMSR products from the SWS-only products (as in the L2B) we have added either the letter “E” (for “empirical”) or “S” (for scatterometer-only). We have added a middle extension to the filename to indicate the data start and end times.

These times are approximately at the rev boundaries, and use the format <YYYYDDDHHMM> where YYYY=2003 for all of the SeaWinds data, and DDD is the Julian day number in the year. The final extension is the processing date/time of the data. [The 12.5km L2A and L2B product filenames have the additional extension “.CP12” appended.] The full filenaming format can be summarized as follows:

SW_S<level><rev number>[E/S].<data start><data end>.<processing time>[.CP12]

7.2 File Organization

All SeaWinds standard products are in Hierarchical Data Format (HDF). HDF is a self-describing data format developed by the National Center for Supercomputing Applications (NCSA) at the University

of Illinois. HDF is the standard data format for Earth Observing System (EOS) satellites. HDF can store large varieties of data structures, which are portable to a large number of computing platforms and are equally accessible to routines written either in C or in FORTRAN. All access to SeaWinds data products using either C or FORTRAN should utilize the NCSA HDF interface library routines (see Section 7.2.1).

All SeaWinds files are created under the UNIX™ operating system. Since these files are in HDF format, however, these data should be portable to most major computing devices, provided the requisite HDF software tools are available.

Each of the SeaWinds Level 1B, 2A and 2B data products is divided into discrete files that are defined by spacecraft ‘revs’. One rev includes all of the data acquired during a single orbital revolution of the spacecraft. By convention, all SeaWinds revolutions begin and end at the southernmost orbital latitude.

Each SeaWinds data product file includes a header. The product header contains multiple metadata elements. The conditions specified by the SeaWinds metadata apply to the entire set of data in the file. The remainder of the file contains either those data acquired by the SeaWinds instrument over the spacecraft measurement swath, or those data that were generated by the SeaWinds software.

7.3 HDF Data Notation

HDF classifies data elements into one of four distinct data classes. These classes include unsigned integers, signed integers, floating point numbers and characters.

HDF class declarations employ the following symbols:

HDF Class	Class Definition
uint	unsigned integer
int	signed integer
float	floating point number
char	character variable

Individual data element class declarations take the form:

class#

where a legal class is one of the symbols in the above table. The subsequent number, represented by the # sign, indicates the number of bits required to store each instance of the data element. Thus, uint16 designates an unsigned integer data element that requires 16 bits of storage space. Valid HDF classes include 8, 16 and 32 bit signed and unsigned integers, 32 and 64 bit floating point numbers, and character strings of variable length.

The HDF library supports six data models and their accompanying interfaces. The NCSA HDF objects, which the SeaWinds Level Processors employ, include Scientific Data Sets (SDS), Vdata, and Global Attributes.

An HDF SDS is a fixed dimensional array. An HDF SDS may contain as many as 32,768 dimensions. All of the elements within an SDS must belong to the same data class, and must require the same amount of storage space. Permissible element classes of an SDS include 8, 16 or 32 bit signed or unsigned integers, and 32 or 64 bit floating point numbers. The HDF SDS model incorporates a set of attributes that describe the data object. Standard attributes specify labels, units, plot scales, display formats, maxima, and minima for each data dimension within the SDS. Attributes can contain any descriptive information, including comments. One set of attributes is associated with each dimension of the SDS. An additional set of attributes describes the entire SDS object.

SDS array notation is similar to the standards of the C programming language where indices are zero based. Thus, the first index in each dimension is zero. This convention is unlike Fortran, where the initial index in each dimension is one. In multidimensional SDS arrays, the rightmost subscript index changes most rapidly. Thus, elements ARRAY[15,0,5] and ARRAY[15,0,6] are stored contiguously.

The Vdata model provides a framework to store customized data records. A Vdata object is a one-dimensional array of records. Each record in a Vdata object contains a set of elements that adhere to a specifically defined template. The template may contain any number of data elements, so long as each element belongs to a standard HDF data class. Thus, every array member within the same Vdata object conforms to exactly the same structural definition. A unique character string can serve as an identifier for a specific Vdata structural template.

HDF Global Attributes function identically to the attributes associated with individual SDS objects. Global Attributes, however, specify characteristics of the full set of data within the entire file instead of a single SDS object in the file.

7.4 Data Definition Standards

Below are explanations for the data attributes used in sections 6.2 to 6.4. In most cases, these explanations include all of the potential values for each attribute. In some situations, a particular attribute may not apply to a data element. In those cases, the attribute field does not appear, or the listing contains the character string 'n/a'. Hexadecimal representation sometimes indicates data content more clearly. Numbers represented in hexadecimal begin with the character string '0x'.

HDF_model: The HDF model that stores the data element. SeaWinds level data products use “scientific data sets”, “Vdata” elements, and “global attributes”. Most SeaWinds data are stored in

scientific data sets. Global attributes are descriptive entries, which are used to store the SeaWinds metadata.

repetition: Repetition count of the data element, when applicable. Array subscript expressions specify the element's dimension. The number of subscripts indicates the number of dimensions. The value of each subscript represents the maximum number of members in the corresponding dimension.

conceptual_type: The type identifier that reflects the data element in concept. This entry is critical, since SeaWinds data are often not stored in the form that matches the concept. Acceptable type values include "string", "time", "boolean", "real", "integer" and "enum".

storage_type: The data representation of the element within the storage medium. The storage class specification must conform to a valid HDF type. The valid HDF class strings are "int8", "int16", "int32", "uint8", "uint16", "uint32", "float32", "float64", and "char".

number_of_bytes: HDF classes indicate the storage space required to store integers and floating point numbers. They do not indicate, however, the storage space required for character strings. This entry lists the number of bytes allocated to store data elements as character strings. This attribute does not appear under floating point number and integer listings.

units: Units of measure. Typical values include "deg", "C", "K", "deg/sec", "Watts", "dB", "m", "m**2", "m/sec", "sec", "DN", "frames", "pulses" and "counts".

minimum_value: The appropriate minimum value for a data element in its conceptual type.

maximum_value: The appropriate maximum value for a data element in its conceptual type.

scale_factor: The factor used to convert the value of a non-string element from its conceptual type to its storage type. By convention, the conversion operation from conceptual type to storage type is always division. Users should remember to include the value of the high order bit when interpreting data elements that are stored as unsigned integers.

offset: The component used to convert the value of a non-string element from its conceptual type to its storage type. By convention, the conversion operation from conceptual type to storage type is always subtraction.

valid_values: Some data elements may store a restricted set of values. In these instances, this attribute appears in the data element entry. This attribute lists those values that the data element may store.

nominal_value: The expected or typical value for a data element in its conceptual type.

SeaWinds time measurements are either character strings or double precision real values. SeaWinds character string time variables are in Coordinated Universal Time (UTC) format. Strings, which specify both the date and the time, contain 21 ASCII characters. The date/time format conforms to the ASCII Day Segmented Time Code B recommended by the Consultative Committee for Space Data Systems (CCSDS). The string format is yyyydddThh:mm:ss.sss. Time accuracy is to the nearest

thousandth of a second. To accommodate leap years, the maximum value in the day of the year field is 366. A maximum value in the seconds field of 60.999 permits leap second addition.

SeaWinds double precision time variables contain measurements in International Atomic Time (TAI). TAI measurements represent the real number of Standard International (SI) compatible seconds since 12:00 AM January 1, 1993 UTC. This initial time is an Earth Observing System Data and Information System (EOSDIS) Core System (ECS) standard. Although the SeaWinds Project does not work directly with the ECS, the SeaWinds Project uses this initial time to generate data that are compatible with data stored in the ECS.

7.5 Coordinate Systems

SeaWinds level data products employ the Earth Centered Rotating (ECR) Coordinate System to specify the location and velocity of the ADEOS-II spacecraft. The ECR coordinate system is right handed. The origin is at the earth's center. The positive x-axis extends from the origin through the intersection of the equator and the prime (Greenwich) meridian. The positive y-axis runs from the origin through the equator at 90 degrees East longitude. The z-axis extends from the origin through the North Pole.

The spacecraft fixed coordinate system is also right handed. The origin is the center of mass of the spacecraft. The y-axis points in the direction of flight, while the z-axis points in the nadir direction. Spacecraft attitude measurements employ a roll-pitch-yaw system relative to these axes. Positive rotations of attitude conform to the right hand rule.

7.6 Metadata

All of the entries in the SeaWinds level product header are metadata. Each header data set encompasses the entire contents of the file.

A set of HDF global attributes stores the metadata. The name of each global attribute that is used for metadata storage matches the name of the metadata element. The contents of each global attribute are ASCII characters. Global attributes that list SeaWinds metadata elements must contain at least three lines. Lines are delimited by the ASCII new-line character.

The first line indicates the metadata type. This entry may contain one of three possible strings:

Metadata Type	Type Definition
int	integer
char	character or character string
float	floating point

The second line indicates the array size. SeaWinds metadata must be single values, one-dimensional arrays, or two-dimensional arrays. For single valued metadata elements, this line lists the integer 1. For one-dimensional arrays, this line contains a single integer that specifies the number of elements in

the array. For two-dimensional arrays, this entry contains two integers that represent the extent of the array's dimensions. The two-dimension specifiers are delimited by a comma.

The third line and all of the lines thereafter list the metadata contents. If the second line indicates that the metadata element is a two-dimensional array, the contents of the array are listed in row major order. In other words, entries with matching first dimension indices and consecutive second dimension indices are listed on consecutive lines.

Metadata elements are character strings that can easily vary in size. Any change in product specification can modify the total number of bytes that are needed to store all of the characters in a metadata element. The number of bytes that are listed for metadata elements are estimates of the maximum number of characters required to store that data element. Software that reads SeaWinds product metadata may use these byte estimates to insure that the complete content of the metadata element is extracted from the SeaWinds data product.

7.7 Data Representation

Unless stated otherwise, all data are in binary format. The term byte is synonymous with the ISO term "octet".

7.7.1 Bit and Byte Format

The basic addressable unit is the 8-bit byte. Multi-byte quantities are addressed by the most significant byte, and hence bytes are stored in order of decreasing significance. A byte is 8 contiguous bits starting on an addressable byte boundary. The bits are numbered 0 through 7 starting from right to left.

Example:

Byte n	Byte n+1	Byte n+2	Byte n+3
31 ... 24	23 ... 16	15 ... 08	07 ... 00

The twos complement system is used for negative numbers. The twos complement representation of a negative number is formed by performing binary subtraction of each digit from 1 and then adding 1 to the least significant digit. For example, the twos complement of 11010011 is 00101101.

8 Acquiring and Extracting the SeaWinds Science Data

8.1 Obtaining the Data

After SeaWinds data processing, the Level 1B and Level 2A data are distributed by PO.DAAC to approved researchers on either 8mm Exabyte tapes or on DLT-7000 tapes.

Level 2B data is distributed by PO.DAAC to all interested researchers on tape or DVD (TBD) media. Level 2B data is also distributed electronically via the PO.DAAC FTP site:

ftp://podaac.jpl.nasa.gov/pub/ocean_wind/SeaWinds

Higher-level SeaWinds data products may also be accessed through the World Wide Web:

<http://podaac.jpl.nasa.gov/SeaWinds>

8.1.1 SeaWinds Science Products

The 8mm tape products contain approximately four days of data (either Levels 1B or 2A) or 45 days of Level 2B data, in HDF format with supporting ancillary data, documentation and software. The Level 1B and Level 2A tapes may each span two tapes per delivery.

The DLT-7000 tape product may contain 12 days of data (Level 1B) or 60 days of Level 2A data, in HDF format with supporting ancillary data, documentation and software.

Each tape consists of one UNIX tar file that contains the following:

- an ASCII file listing of the package contents;
- the data files in HDF format;
- the ‘in-line’ quality assurance files (if available);
- spacecraft revolution versus time data, REV_TIME.DAT;
- the SeaWinds quality assurance report associated with this batch of data;
- the C, FORTRAN, and IDL readers, provided by the PO.DAAC;
- data documentation, (user’s manual and SIS documents.)

The product will be physically labeled to indicate the product level, the data start and stop times, and the tape creation time.

8.1.2 Network Access

Supporting software, documentation and higher-level data products (Level 2B and above) will be available on the PO.DAAC FTP site: <ftp://podaac.jpl.nasa.gov>. These files are located in the FTP directory /pub/ocean_wind/SeaWinds in the following subdirectories:

Level 2B data	data/L2B/
Level 3 data	Data/L3/
Rev vs. Time, QA report	data/mission_status_report/
Software	software/
Documentation	doc/

8.2 Reading the SeaWinds Data

Sample read software for the SeaWinds data are available in C, FORTRAN and Interactive Data Language (IDL). These programs can be easily modified to meet the requirements of individual users. Please contact the PO.DAAC SeaWinds Data Team (SeaWinds@podaac.jpl.nasa.gov) if you encounter any difficulty while using this software.

Program Name	Description	Notes
read_sws_info.c	C program to read the attributes in Levels 1B, 2A and 2B	1
read_sws1Bez.c	Simple C program to read the Level 1B data	1
read_sws1B.c	More standard C program to read the Level 1B data	1
read_sws2Aez.c	Simple C program to read the Level 2A data	1
read_sws2A.c	More standard C program to read the Level 2A data	1
read_sws2Bez.c	Simple C program to read the Level 2B data	1
read_sws2B.c	More standard C program to read the Level 2B data	1
read_sws3ez.c	Simple C program to read the Level 3 data	1
read_sws3.c	More standard C program to read the Level 3 data	1
read_sws_info.f	FORTRAN program to read the attributes in Levels 1B, 2A and 2B	1
read_sws1b.f	FORTRAN program to read the Level 1B data	1
read_sws2a.f	FORTRAN program to read the Level 2A data	1
read_sws2b.f	FORTRAN program to read the Level 2B data	1
read_sws3.f	FORTRAN program to read the Level 3 data	1
read_sws_info.pro	IDL program to read the attributes in Levels 1B, 2A and 2B	2
read_sws1b.pro	IDL program to read the Level 1B data	2
read_sws2a.pro	IDL program to read the Level 2A data	2
read_sws2b.pro	IDL program to read the Level 2B data	2
read_sws3.pro	IDL program to read the Level 3 data	2

Notes:

- (1) The HDF library must be installed locally before the read software in C or FORTRAN will work properly. The HDF library and further information about HDF may be obtained from the NCSA HDF web site at <http://hdf.ncsa.uiuc.edu>.
- (2) IDL is a software tool used for the analysis and display of scientific data. It is a registered trademark of Research Systems, Inc. The installation of the HDF library is not necessary in order to use the IDL read software, because IDL already contains the HDF library.

9 Appendices

9.1 PO.DAAC Points of Contact

Questions and comments concerning the SeaWinds Science Data Products should be directed to PO.DAAC. Please note that e-mail is always the preferred method of communication.

E-mail:	sws@podaac.jpl.nasa.gov
Home Page:	http://podaac.jpl.nasa.gov/SeaWinds
FTP:	ftp://podaac.jpl.nasa.gov
Telephone:	+1-626-744-5508
Fax:	+1-626-744-5506
By mail:	JPL PO.DAAC User Services Office Jet Propulsion Laboratory Mail Stop Raytheon-299 4800 Oak Grove Drive Pasadena, CA 91109 U.S.A.

9.2 Definitions of Commonly-Used Terms

Ambiguity Removal Also called the ambiguity selection process. This is the process of selecting the best wind vector field from the wind solutions retrieved from the scatterometer measurements within each wind vector cell. The SeaWinds data level processing software performs ambiguity removal using a median filter.

Doppler Binning A technique used on SeaWinds to adjust the σ_o cell bandpass frequencies as a function of orbit location in order to maintain accurate beam-to-beam cell co-registration and constant swath location. The processing of return signals is controlled by a binning parameter table, which is used by the on-board processor to divide the received power into cells in the frequency domain, and is used in the ground processing to perform Earth location of the σ_o cells. The binning parameter table for a given swath layout and cell resolution depends mainly on the spacecraft orbit.

Model Function The relationship between normalized radar backscatter cross-section (σ_o) and wind velocity. The model function is known to be a function of wind speed, wind direction relative to the look angle, incidence angle, and radar polarization. Other, possibly significant, uncalibrated parameters include sea surface temperature, sea state, and salinity. For SeaWinds, the model function is cast in a tabular form.

Wind Retrieval The process of finding the set of wind vector solutions representing the best fit of the σ_o measurements to the model function. Since the model function gives σ_o as a function of wind velocity, the wind retrieval process attempts to invert the model function to derive the wind solutions. The SeaWinds algorithm is a non-linear search for extrema of a maximum-likelihood objective function.

NWP “Nudging” The median filter ambiguity removal algorithm requires an initial field of wind vector solutions in order to begin the selection process. The NWP “nudging” technique, first developed for ERS-1 and NSCAT processing by Dunbar and Freilich, uses a Numerical Weather Prediction (NWP) model to assist the initialization of the ambiguity removal algorithm. Either the first or the second ranked SeaWinds wind vector, whichever is closer to the direction of NWP wind vector, is chosen as the initial guess used by the ambiguity removal algorithm. When no suitable NWP field is available, the processing reverts to using the first-ranked wind vector solutions to initialize the algorithm.

9.3 Abbreviations and Acronyms

This is the standard SeaWinds Processing and Analysis System (SeaPAC) list of acronyms and abbreviations. Not all of these acronyms and abbreviations appear in every SeaWinds/ ADEOS-II document.

ADEOS	Advanced Earth Observing Satellite (Japan)
AMSR	Advanced Microwave Scanning Radiometer
ANSI	American National Standards Institute
APC	Antenna Pattern Correction
ASA	Antenna Switching Assembly

BPF	Band Pass Filter
C	degrees Celsius
CCB	Configuration Control Board
CCSDS	Consultative Committee on Space Data Systems
CDE	Cognizant Development Engineer
CDR	Critical Design Review
CDS	Command and Data Subsystem
CR	Change Request
CRC	Cyclic Redundancy Code
dB	decibels
dB_i	decibels isotropic
dB_m	decibels relative to 1 milliwatt
DBW	decibels relative to 1 watt
DDE	Data Dictionary Entry
deg	degrees (angle)
deg/sec	degrees per second
DIU	Digital Interface Unit
DN	Data Number
DSS	Digital Subsystem
EA	SeaPAC Engineering Analysis program set
ECI	Earth Centered Inertial Coordinate System
ECR	Earth Centered Rotating Coordinate System
ECS	EOSDIS Core System
EOC	Earth Observation Center (Japan)
EOSDIS	Earth Observing System Data and Information System
EPHD	Determined Ephemeris
EPHP	Predicted Ephemeris
ESDIS	Earth Science Data and Information System Project
ESDT	Earth Science Data Type
EU	Engineering Unit
FRB	Functional Requirements Baseline
FTP	File Transfer Protocol
FTS	File Transfer Server
FX	SeaPAC File Transfer program set
GPS	Global Positioning System
GHA	Greenwich Hour Angle
GMST	Greenwich Mean Sidereal Time
HDF	Hierarchical Data Format
HK1	SeaWinds Playback Spacecraft Housekeeping Data

HVPS	High Voltage Power Supply
Hz	Hertz
ICD	Interface Control Document
IDP	Instrument Data Processor
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IF	Intermediate Frequency
ISO	International Organization for Standardization
JPL	Jet Propulsion Laboratory
K	Kelvin (degrees of absolute temperature)
LAD	Latest-available-data
LAN	Local Area Network
LMDR	Low Mission Data-rate Recorder
LOE	Level Of Effort
LFMC	Linear Frequency Modulation Chirp
LP	SeaPAC Level Processor program set
MLE	Maximum Likelihood Estimator
m	meters
m/sec	meters per second (also m/s)
msec	milliseconds
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan
NCEP	National Center for Environmental Prediction
NCSA	National Center for Supercomputing Applications
NERT	Near Real Time
NFS	Network File System/Server
NIC	National Ice Center
NOAA	National Oceanic and Atmospheric Administration
NOP	No Operation
NORDA	Naval Ocean Research Development Activity
NSCAT	NASA Scatterometer
NWP	Numerical Weather Prediction
n/a	not applicable
OCL	Operations Coordination Letter
ODL	Object Description Language
OIS	Operational Interface Specification
PBI	Payload Bus Interface
PCD	Platform Control Data

PCU	Power Converter Unit
PEC	Precision External Clock
PM	SeaPAC Process Management program set
PO.DAAC	Physical Oceanography Distributed Active Archive Center
PP	SeaPAC Preprocessor program set
PR	Problem Report
PRF	Pulse Repetition Frequency
PROM	Programmable Read Only Memory
PSU	Power Switching Unit
PVL	Parameter Value Language
QuikSCAT	NASA's Quick Scatterometer
RAM	Random Access Memory
RDD	Release Description Document
RF	Radio Frequency
RFA	Request For Action
RFS	Radio Frequency Subsystem
RIU	Remote Interface Unit
rms	Root Mean Square
ROM	Read Only Memory
S/C	Spacecraft
SA	SeaPAC Science Analysis program set
SAA	Spin Actuator Assembly
SAS	SeaWinds Antenna Subsystem
SCCLK	Spacecraft Clock
SCF	Science Computing Facility
SDS	Scientific Data Set
SE	System Engineer
SeaPAC	SeaWinds Processing and Analysis Center
SES	Scatterometer Electronic Subsystem
SI	Standard International
sigma0	Normalized radar cross section (σ_0)
SIS	Software Interface Specification
SITP	System Integration and Test Plan
snr	signal to noise ratio
SOM	Software Operators Manual
SPARCä	Sun™ Scalable Processor Architecture
SRB	Software Requirements Baseline
SRD	Software Requirements Document
SRM	System for Resource Management

SSD	Software Specifications Document
SSM/I	Special Sensor Microwave/Imager
STALO	Stable Local Oscillator
STP	Software Test Plan
SWT	Science Working Team
sec	seconds
TAI	International Atomic Time
TBD	To Be Determined
TCP/IP	Transmission Control Protocol/Internet Protocol
TRS	Transmit Receive Switch
TSR	Technical Status Review
TWT	Traveling Wave Tube
TWTA	Traveling Wave Tube Amplifier
UTC	Coordinated Universal Time
VTCW	Vehicle Time Code Word
WTS	Waveguide Transfer Switch
WVC	Wind Vector Cell

9.4 Scatterometry References and Bibliography

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*** QuikSCAT Science Data Product Users Manual, Overview & Geophysical Data Product, Editor: Perry, K.L., JPL D-18503 Jet Propulsion Laboratory, Pasadena, CA, March 2001

Collections:

"NSCAT: Scientific Applications," American Geophysical Union collection of NSCAT papers reprinted from *J. Geophys. Res.*, *Geophys. Res. Letters*, *Eos*, *Transactions*, AGU, 1999.

9.5 Links To Background Documentation & Support Materials

List of referenced support packages :

[Stiles1] "SeaWinds Empirical Rain Correction Using AMSR", [EmpRainCorrPackage.ppt](#)

- [Stiles2] “SeaWinds AMSR-derived Impact Table”, [ImpactTablePackage.ppt](#)
- [Stiles3] “SeaWinds IMUDH Flag Choice”, [SWSIMUDHPackage.ppt](#)
- [Stiles4] “SeaWinds Error Bars Overview”, [ErrorBarPackage.ppt](#)
- [Veleva1] [Description_AMSR_Algorithms.doc](#)

9.6 Data Correspondence between the Level 2A and Level 2B Products

The Level 2B Processor uses the σ_0 values in the Level 2A Product to generate winds over the ocean's surface. Since the organization of the Level 2A and Level 2B Products are considerably different, the correspondence between the σ_0 values in the Level 2A Product and the winds generated from those σ_0 values in the Level 2B Product is not straightforward.

Two data elements in the Level 2A Product specify the Level 2B wind vector cell where each σ_0 lies. These elements are the `row_number` and the `cell_index`.

To demonstrate the use of these two data elements, assume a data element `sigma0[i,j]` that is located within the spacecraft rev, which is designated in the name of a Level 2A Product file. `Sigma0[i,j]` is the (j-1)th `sigma0` in the (i-1)th row of the Level 2A Product. Element `row_number[i]` specifies the wind vector cell row where `sigma0[i,j]` is located. Element `cell_index[i,j]` specifies the wind vector cell where `sigma0[i,j]` is located.

In other words, if

$$m = \text{row_number}[i] - 1$$

and

$$n = \text{cell_index}[i,j] - 1,$$

then the ordered pair `[m,n]` specifies the location of the elements in the Level 2B Product which were generated using `sigma0[i,j]`. Thus, `wind_speed[m,n,0]` and `wind_dir[m,n,0]` in the Level 2B Product are the wind speed and wind direction of the ambiguity with the highest `max_likelihood_est` for the wind vector cell where `sigma0[i,j]` is located in the Level 2A Product. Users should note that `sigma0[i,j]` represents just one of several scatterometer measurements which contribute to the same wind vector solution.

This reasoning applies only for those σ_0 values that lie within the rev that is designated in the name of the Level 2A Product file. The first 39 wind vector cell rows in each Level 2A file represent measurements that are located in the spacecraft rev that precedes the one specified in the file name. The final 39 wind vector cell rows in each Level 2A file represent measurements that are located in the spacecraft rev that follows the one specified in file name. Thus, the Level 2B Processor does not use any of the σ_0 values in the first 39 or last 39 wind vector cell rows of the input Level 2A Product for wind retrieval.

9.7 Selected Element Definitions

9.7.1 Complete Level 3 Definitions

9.6.1.1 ancillary_data_descriptors

An array of file names, which specifies all of the ancillary data, files which were used to generate this output product. Ancillary data sets include all Level Processor input except for the primary input files.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	2576
units:	n/a
minimum_value:	n/a
maximum_value:	n/a

9.6.1.2 build_id

A character string that identifies the version of the SeaPAC software that was used to generate this data file. The build_id has the format x.y.z.n-m/yyyy-mm-dd where x.y.z.n-m is the version identification number and yyyy-mm-dd is the date that the software build was completed.

The final four characters in the version identification number are optional. Thus, the form of the version identification number may be simply x.y.z or x.y.z.n.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	40
units:	n/a
minimum_value:	n/a
maximum_value:	n/a

9.6.1.3 data_format_type

A character string that describes the internal format of the data product. This value indicates which software tools or which types of program language statements are necessary in order to read the data product file.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	32
units:	n/a
minimum_value:	n/a
maximum_value:	n/a

valid_values: 'NCSA HDF'

9.6.1.4 EquatorCrossingDate

The date of the equator crossing of the spacecraft nadir track in the ascending direction. The format of the date listing is YYYY-DDD, where YYYY represents the calendar year, and DDD represents the day of the year.

The Level 3 Product lists one EquatorCrossingDate value for each input Level 2B file. The index of the EquatorCrossingDate value in the array corresponds to the index of the Level 2B input file listed in the InputPointer metadata element.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	272
units:	n/a
minimum_value:	1993-001
maximum_value:	2016-366

9.6.1.5 EquatorCrossingLongitude

The interpolated longitude of the equator crossing of the spacecraft nadir track in the ascending direction.

The Level 3 Product lists one EquatorCrossingLongitude value for each input Level 2B file. The index of the EquatorCrossingLongitude value in the array corresponds to the index of the Level 2B input file listed in the InputPointer metadata element.

HDF_model:	global attributes
conceptual_type:	real
storage_type:	char
number_of_bytes:	272
units:	deg
minimum_value:	0.000
maximum_value:	359.999

9.6.1.6 EquatorCrossingTime

The interpolated time of the equator crossing of the spacecraft nadir track in the ascending direction. The format of the time listing is HH:MM:SS.ddd where HH represents the hour in twenty four hour time, MM represents the minutes, SS represents the seconds, and ddd represents thousandths of a second. To accommodate the possibility of leap seconds, the maximum value for the number of seconds is 60.999.

The Level 3 Product lists one EquatorCrossingTime value for each input Level 2B file. The index of the EquatorCrossingTime value in the array corresponds to the index of the Level 2B input file listed in the InputPointer metadata element.

HDF_model:	global attributes
conceptual_type:	time
storage_type:	char
number_of_bytes:	272
units:	n/a
minimum_value:	00:00:00.000
maximum value:	23:59:60.999

9.6.1.7 GranulePointer

A pointer to the output data granule. The ECS requires this metadata element for all full class products. Users may employ this mandatory value to locate particular records within the ECS database. For products in the SeaPAC environment, this element contains the name of the output product. For those products that are delivered from an ECS environment, this element contains an ECS specific pointer.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	272
units:	n/a
minimum_value:	n/a
maximum_value:	n/a

9.6.1.8 grid_cell_quality_flag

Bit flags that indicate the quality of a Level 3 grid cell location.

The significance of each of the bit flags is as follows:

Bit	Definition
0	Data Exists Flag 0 - Data was located for this L3 grid cell. 1 - Data was not located for this L3 grid cell.
1	Multiple WVC Flag 0 - Only one data set was located within this L3 grid cell. 1 - More than one data set was located within this L3 grid cell.
2	Data Overwritten Flag 0 - Data in this L3 grid cell was not overwritten. 1 - Data in this L3 grid cell was overwritten.
3	Rain Flag Usable

- 0 - The rain flag is usable.
1 - The rain flag is not usable.
- 4 Rain Flag
- 0 - Rain was not detected.
1 - Rain was detected.
- 5 Available Data Flag
- 0- Inner beam data with SeaWinds view forward and aft and outer beam data with SeaWinds view forward and aft are available.
1- Data from at least one of the four possible beam and view combinations are not available.
- 6 Attenuation Correction Flag
- 0- Attenuation corrections were applied to sigma0s used to retrieve winds.
1- Attenuation corrections were not applied to sigma0s used to retrieve winds.
- 7-8 Attenuation Source Flag
- 0- AMSR brightness temperatures were used to correct sigma0s for atmospheric attenuation.
1- The climatological attenuation map was used to correct sigma0s for atmospheric attenuation.
2- The apparent brightness temperatures based on scatterometer measurements were used to correct sigma0s for atmospheric attenuation.
3- N/A
- 9 Coastal Flag
- 0- No land mass was detected within this L3 grid cell.
1- Some portion of this L3 grid cell is over land.
- 10 Ice Edge Flag
- 0- No ice was detected within this L3 grid cell.
1- Some portion of this L3 grid cell is over ice.
- 11 AMSR Rain Indicator Flag
- 0 - The reported AMSR rain indicator value is usable.
1 - The reported AMSR rain indicator value is not usable.

12-15 Spare. Always clear (0)

HDF_model:	scientific data set
conceptual_type:	integer
storage_type:	uint16
number_of_bytes:	2

units:	n/a
minimum_value:	0x0000
maximum_value:	0x0FFF
scale_factor:	1

9.6.1.9 grid_cell_spare

Spare bytes reserved for future extension to the Level 3 Product.

HDF_model:	scientific data set
conceptual_type:	integer
storage_type:	uint3
number_of_bytes:	4
units:	n/a
minimum_value:	n/a
maximum_value:	n/a
scale_factor:	1

9.6.1.10 HDF_version_id

A character string that identifies the version of the HDF (Hierarchical Data Format) software that was used to generate this data file. NCSA (National Center for Supercomputing Applications) at the University of Illinois develops HDF software.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	40
units:	n/a
minimum_value:	n/a
maximum_value:	n/a

9.6.1.11 InputPointer

Pointers to the major input data granules that were used to generate this product. The ECS requires this metadata element for all full class products. Users may employ this mandatory value to locate particular records within the ECS database. For products in the SeaPAC environment, this element contains the name of the input data granules. For those products that are delivered from an ECS environment, this element contains ECS specific pointers.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	4112
units:	n/a
minimum_value:	n/a
maximum_value:	n/a

9.6.1.12 InstrumentShortName

The name of the instrument that collected the telemetry data.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	36
units:	n/a
minimum_value:	n/a
maximum_value:	n/a
valid values:	'SeaWinds'

9.6.1.13 l3_actual_grid_cells

The actual number of grid cells in the Level 3 Product for which wind vector data exists.

When computing this number the Level 3 Processor views one virtual grid that is composed of the ascending phase grid overlaid on top of the descending phase grid. Cells where the phases overlap are only counted once.

HDF_model:	global attributes
conceptual_type:	integer
storage_type:	char
number_of_bytes:	24
units:	grid cells
minimum_value:	0
maximum_value:	1036800

9.6.1.14 l3_actual_grid_cells_asc

The actual number of grid cells in the Level 3 Product for which ascending wind vector data exists. When computing this number the Level 3 Processor views only the ascending phase grid.

HDF_model:	global attributes
conceptual_type:	integer
storage_type:	char
number_of_bytes:	24
units:	grid cells
minimum_value:	0
maximum_value:	1036800

9.6.1.15 l3_actual_grid_cells_dsc

The actual number of grid cells in the Level 3 Product for which descending wind vector data exists.

When computing this number the Level 3 Processor views only the descending phase grid.

HDF_model:	global attributes
------------	-------------------

conceptual_type:	integer
storage_type:	char
number_of_bytes:	24
units:	grid cells
minimum_value:	0
maximum_value:	1036800

9.6.1.16 l3_algorithm_descriptor

A set of character strings that list important details about the implementation of the Level 3 Processor algorithm which were used to generate this product.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	656
units:	n/a
minimum_value:	n/a
maximum_value:	n/a

9.6.1.17 LongName

A complete descriptive name for the product. The LongName serves as an ECS data set identifier. This character string identifies each Earth Science Data Type (ESDT) in the ECS library. The ECS requires this metadata element for all products.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	96
units:	n/a
minimum_value:	n/a
maximum_value:	n/a
valid_values:	'SeaWinds Level 3 Ocean Wind Vectors in a 0.25 Degree Global Grid'

9.6.1.18 null_data_indicator

A flag that indicates whether data at a Level 3 grid cell location is null. This flag is set to 0 if the Data Exists Flag (bit 0) is set to 0 in grid_cell_quality_flag. This flag is set to 1 otherwise. A value of 0 indicates that the data is usable. A value of 1 indicates that the data is null and should not be used.

HDF_model:	scientific data set
conceptual_type:	integer
storage_type:	uint8

number_of_bytes:	1
units:	n/a
minimum_value:	0
maximum_value:	1
scale_factor:	1

9.6.1.19 num_l3_columns

The number of columns in the Level 3 Product grid.

HDF_model:	global attributes
conceptual_type:	integer
storage_type:	char
number_of_bytes:	24
units:	columns
minimum_value:	1
maximum_value:	1440
nominal_value:	1440

9.6.1.20 num_l3_rows

The number of rows in the Level 3 Product grid.

HDF_model:	global attributes
conceptual_type:	integer
storage_type:	char
number_of_bytes:	24
units:	rows
minimum_value:	1
maximum_value:	720
nominal_value:	720

9.6.1.21 observation date

The date that the output data granule represents. The format of the date listing is YYYY-
DDD, where YYYY represents the calendar year, and DDD represents the day of the year.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	32
units:	n/a
minimum_value:	1993-001
maximum_value:	2016-366

9.6.1.22 OperationMode

This character string specifies a SeaWinds instrument mode. The instrument mode can vary within a single data granule. To determine an appropriate listing, Operation-Mode views the SeaWinds instrument modes in a hierarchical order. 'Wind Observation' is the highest mode in the hierarchy, followed by 'Receive Only', 'Calibration' and 'Standby' in that order. OperationMode lists the highest level instrument mode that was recorded in the associated data granule. Thus, if a single telemetry frame in the entire data granule records 'Wind Observation' mode, then the value of OperationMode is 'Wind Observation'.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	40
units:	n/a
minimum_value:	n/a
maximum_value:	n/a
valid values:	'Wind Observation'

9.6.1.23 OrbitParametersPointer

A pointer to one data granule or a set of data granules that provide the orbit parameters that are used to generate the data in this product. For products in the Sea-PAC environment, this element contains the names of the ephemeris data granules. For those products that are delivered from an ECS environment, this element contains one or several ECS specific pointers.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	2576
units:	n/a
minimum_value:	n/a
maximum_value:	n/a

9.6.1.24 Parameter Name

ParameterName specifies one of the data elements in a SeaWinds Level Product. The data element specified by ParameterName is the element that the Level Processor uses to calculate QAPercentOutOfBoundsData and QAPercentMissingData.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	40
units:	n/a
minimum_value:	n/a
maximum_value:	n/a
valid values:	rep_wind_speed

9.6.1.25 percent_rev_data_usage

The percent of the product that contains data from a particular rev. The Level 3 Product lists one percent_rev_data_usage value for each input Level 2B file. The index of the percent_rev_data_usage value in the array corresponds to the index of the Level 2B input file listed in the InputPointer metadata element.

HDF_model:	global attributes
conceptual_type:	real
storage_type:	char
number_of_bytes:	272
units:	n/a
minimum_value:	0.000
maximum_value:	100.000

9.6.1.26 PlatformLongName

The complete, descriptive name of the platform associated with the test instrument.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	96
units:	n/a
minimum_value:	n/a
maximum_value:	n/a
valid_values:	'Advanced Earth Observing Satellite II'

9.6.1.27 PlatformShortName

A unique identifier for the platform associated with the test instrument.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	24
units:	n/a
minimum_value:	n/a
maximum_value:	n/a
valid_values:	'ADEOS-II'

9.6.1.28 PlatformType

The type of platform associated with the test instrument that acquires the accompanying data.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char

number_of_bytes:	32
units:	n/a
minimum_value:	n/a
maximum_value:	n/a
valid_values:	'spacecraft'

9.6.1.29 producer_agency

Identification of the agency that provides the project funding.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	24
units:	n/a
minimum_value:	n/a
maximum_value:	n/a
valid_values:	'NASA'

9.6.1.30 producer institution

Identification of the institution that provides project management.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	24
units:	n/a
minimum_value:	n/a
maximum_value:	n/a
valid_values:	'JPL'

9.6.1.31 ProductionDateTime

Wall clock time when this data file was created. This time character string expression uses UTC format.

HDF_model:	global attributes
conceptual_type:	time
storage_type:	char
number_of_bytes:	40
units:	n/a
minimum_value:	1993-001100:00:00.000
maximum_value:	2016-366123:59:60.999

9.6.1.32 project_id

The project identification string.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	32
units:	n/a
minimum_value:	n/a
maximum_value:	n/a
valid_values:	'SeaWinds'

9.6.1.33 QAGranulePointer

A pointer to the quality assurance granule that was generated with this product. Users may employ this mandatory metadata element to evaluate the quality of particular records within the ECS database. For products in the SeaPAC environment, this element contains the name of the quality assurance granule. For those products that are delivered from an ECS environment, this element contains an ECS specific pointer.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	272
units:	n/a
minimum_value:	n/a
maximum value:	n/a

9.6.1.34 QAPercentMissingData

The percent of instances when a particular data element within the data product is missing. This value is among the ECS mandatory quality assurance elements. Metadata element ParameterName specifies which data element within the product provides the basis to calculate QAPercentMissingData.

HDF_model:	global attributes
conceptual_type:	integer
storage_type:	char
number_of_bytes:	24
units:	percent
minimum_value:	0
maximum_value:	100

9.6.1.35 QAPercentOutOfBoundsData

The percent of instances when a particular data element within the data product is out of bounds. This value is among the ECS mandatory quality assurance elements. Metadata element

ParameterName specifies which data element within the product provides the basis to calculate QAPercentOutOfBoundsData.

HDF_model:	global attributes
conceptual_type:	integer
storage_type:	char
number_of_bytes:	24
units:	percent
minimum_value:	0
maximum_value:	100

9.6.1.36 rain_flag

A flag that indicates whether rain was detected at a Level 3 grid cell location. This flag is set to 0 if the Rain Flag Usable (bit 3) and the Rain Flag (bit 4) are set to 0 in grid_cell_quality_flag. This flag is set to 1 otherwise.

A value of 0 indicates that rain was not detected. A value of 1 indicates that rain was detected.

HDF_model:	scientific data set
conceptual_type:	integer
storage_type:	uint8
number_of_bytes:	1
units:	n/a
minimum_value:	0
maximum_value:	1
scale_factor:	1

9.6.1.37 RangeBeginningDate

The initial date for data coverage within this SeaWinds data product. The format of the date listing is YYYY-DDD, where YYYY represents the calendar year, and DDD represents the day of the year. In the Level 3 Product, this date is equivalent to the RangeBeginningDate of the first input data granule.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	32
units:	n/a
minimum_value:	1993-001
maximum_value:	2016-366

9.6.1.38 RangeBeginningTime

The initial time for data coverage within this SeaWinds data product. This time is equivalent to the moment the spacecraft passes over the southernmost point in its orbital path. The format of the time listing is HH:MM:SS.ddd where HH represents the hour in twenty four hour time, MM

represents the minutes, SS represents the seconds, and ddd represents thousandths of a second. To accommodate the possibility of leap seconds, the maximum value for the number of seconds is 60.999.

In the Level 3 Product, this date is equivalent to the RangeBeginningTime of the first input data granule.

HDF_model:	global attributes
conceptual_type:	time
storage_type:	char
number_of_bytes:	32
units:	n/a
minimum_value:	00:00:00.000
maximum_value:	23:59:60.999

9.6.1.39 RangeEndingDate

The final date for data coverage within this SeaWinds data product. The format of the date listing is YYYY-DDD, where YYYY represents the calendar year, and DDD represents the day of the year.

In the Level 3 Product, this date is equivalent to the RangeEndingDate of the last input data granule.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	32
units:	n/a
minimum_value:	1993-001
maximum_value:	2016-366

9.6.1.40 RangeEndingTime

The final time for data coverage within this SeaWinds data product. This time is equivalent to the moment the spacecraft passes over the southernmost point in its orbital path. The format of the time listing is HH:MM:SS.ddd where HH represents the hour in twenty four hour time, MM represents the minutes, SS represents the seconds, and ddd represents thousandths of a second. To accommodate the possibility of leap seconds, the maximum value for the number of seconds is 60.999.

In the Level 3 Product, this date is equivalent to the RangeEndingTime of the last input data granule.

HDF_model:	global attributes
conceptual_type:	time
storage_type:	char
number_of_bytes:	32
units:	n/a
minimum_value:	00:00:00.000
maximum value:	23:59:60.999

9.6.1.41 rep_amsr_rain_indicator

The representative AMSR rain indicator for a Level 3 grid cell location. Rep_amsr_rain_indicator is a non-dimensional parameter that reflects the ambient atmospheric conditions. The table below lists three ranges of rain indicator values, specifies the atmospheric conditions that are typical for those numerical ranges, and describes the relative effect of those conditions upon the backscatter signal detected by the SeaWinds instrument:

Rain Indicator Range	Atmospheric Condition and the Effect on the Scatterometer Echo Signal
Less than 0.5	Clear sky or cloudy conditions. Atmosphere attenuates backscatter signal
Between 0.5 and 4.0	Light to moderate rain conditions. Atmospheric phenomena attenuate the backscatter signal. Most of the attenuation is due to precipitating hydrometeors.
Greater than 4.0	Heavy rain conditions. Backscatter generated by hydrometeors in the atmosphere dominates the surface echo signal. Phenomena that attenuate the backscatter signal are less important by comparison.

The value is retrieved using observations of the Advanced Microwave Scanning Radiometer (AMSR).

HDF_model: scientific data set
conceptual_type: real
storage_type: int16
number_of_bytes: 2
units: n/a
minimum_value: -20.00
maximum_value: 100.00
scale_factor: 0.01

9.6.1.42 rep_atten_corr

The representative atmospheric nadir attenuation for the Level 3 grid cell location.

HDF_model: scientific data set
conceptual_type: real
storage_type: int16
number_of_bytes: 2
units: dB
minimum_value: 0.000
maximum_value: 32.767
scale_factor: 0.001

9.6.1.43 rep_rain_probability

The rain probability for a Level 3 grid cell location. This value indicates the probability of a columnar rain rate that is greater than 2 km*mm/hr.

HDF_model:	scientific data set
conceptual_type:	real
storage_type:	uint16
number_of_bytes:	2
units:	n/a
minimum_value:	0.000
maximum_value:	1.000
scale_factor:	0.001

9.6.1.44 rep_srad_rain_rate

The representative rain rate for a Level 3 grid cell location. These rain rates are based on 13.402 GHz brightness temperatures that were generated using the noise energy level in the echo channel of the SeaWinds instrument.

HDF_model:	scientific data set
conceptual_type:	real
storage_type:	int16
number_of_bytes:	2
units:	mm/hr
minimum_value:	0.000
maximum_value:	50.000
scale_factor:	0.01

9.6.1.45 rep_time_of_day

The time of day that data was acquired for a Level 3 grid cell location. The time is represented as a fraction of the day. A value of 0.0000 corresponds to 00:00:00.000 UTC. A value of 0.9999 corresponds to 23:59:59.999 UTC.

HDF_model:	scientific data set
conceptual_type:	real
storage_type:	uint16
number_of_bytes:	2
units:	n/a
minimum_value:	0.0000
maximum_value:	0.9999
scale_factor:	0.0001

9.6.1.46 rep_wind_speed

The wind speed for a Level 3 grid cell location.

HDF_model: scientific data set
conceptual_type: real
storage_type: uint16
number_of_bytes: 2
units: m/sec
minimum_value: 0.00
maximum_value: 50.00
scale_factor: 0.01

9.6.1.47 rep_wind_velocity_u

The U component of the wind velocity vector for a Level 3 grid cell location. This value is positive for winds blowing from the West to the East, and represents zonal winds.

HDF_model: scientific data set
conceptual_type: real
storage_type: int16
number_of_bytes: 2
units: m/sec
minimum_value: -50.00
maximum_value: 50.00
scale_factor: 0.01

9.6.1.48 rep_wind_velocity_v

The V component of the wind velocity vector for a Level 3 grid cell location. This value is positive for winds blowing from the South to the North, and represents meridional winds.

HDF_model: scientific data set
conceptual_type: real
storage_type: int16
number_of_bytes: 2
units: m/sec

minimum_value: -50.00
maximum_value: 50.00
scale_factor: 0.01

9.6.1.49 ShortName

The short name used to identify all data granules in a given data collection. The short name provides the official reference for all of the contents of a particular data collection.

HDF_model: global attributes
conceptual_type: string
storage_type: char
number_of_bytes: 24

units:	n/a
minimum_value:	n/a
maximum_value:	n/a
valid_values:	'SWSL3'

9.6.1.50 sis_id

A character string that specifies which version of Software Interface Specification (SIS) document describes the organization and format of data in the file. The complete format of the sis_id is nnn-*nnn*-n-RevZ/yyyy-mm-dd.

The substring nnn-*nnn*-n represents the document identification number.

The substring '-RevZ' represents the level of the current revision. The revision string is optional. This string of characters does not appear in the sis_id of the first official release of a document. The sis_id of each subsequent official release does contain a revision string. The Z represents an upper case letter of the alphabet. Thus, a sis_id with the string '-RevC' represents the third revision of the original official document.

The substring yyyy-mm-dd represents the date of issue.

HDF_model:	global attributes
conceptual_type:	string
storage_type:	char
number_of_bytes:	40
units:	n/a
minimum_value:	n/a
maximum_value:	n/a

9.6.1.51 StartOrbitNumber

The orbit number that corresponds to the data at the beginning of the granule. Orbit numbers reflect spacecraft orbital history. Orbit numbers change at ascending node.

HDF_model:	global attributes
conceptual_type:	integer
storage_type:	char
number_of_bytes:	24
units:	counts
minimum_value:	1
maximum value:	99999

9.6.1.52 StopOrbitNumber

The orbit number that corresponds to the data at the end of the granule. Orbit numbers reflect spacecraft orbital history. Orbit numbers change at ascending node.

HDF_model: global attributes
conceptual_type: integer
storage_type: char
number_of_bytes: 24
units: counts
minimum_value: 1
maximum_value: 99999

9.6.1.53 wind_vector_cell_resolution

The size of one side of the Level 2B wind vector cells used by the Level 3 Processor.

HDF_model: string
conceptual_type: global attributes
storage_type: char
number_of_bytes: 48
units: n/a
minimum_value: n/a
maximum_value: n/a
valid_values: '12.5km','20.0km','25.0km'
nominal_value: '25.0km'

9.6.1.54 wind_vector_source

The source of the wind vector data used by the Level 3 Processor.

The table below lists the speed and direction sources for each of the three possible values of wind vector source.

Wind_Vector_Source Value	Level 2B Source
Direction Interval Retrieval	wind_speed_selection and wind_dir_selection
Selected Ambiguity	wind_speed and wind_dir (uses value of wvc_selection as an index)
First Ambiguity	wind_speed and wind_dir (uses a value of 1 as the index)

HDF_model: global attributes
conceptual_type: string
storage_type: char
number_of_bytes: 32
units: n/a
minimum_value: n/a
maximum_value: n/a
valid_values: 'Direction Interval Retrieval',
'Selected Ambiguity', 'First Ambiguity'

9.7.2 Selected Level 2B Definitions

9.7.2.1 amsr_rain_indicator

A non-dimensional parameter that reflects the ambient atmospheric conditions. The table below lists three ranges of rain indicator values, specifies the atmospheric conditions that are typical for those numerical ranges, and describes the relative effect of those conditions upon the backscatter signal detected by the SeaWinds instrument:

Rain Indicator Range	Atmospheric Condition and the Effect on the Scatterometer Echo Signal
Less than 0.5	Clear sky or cloudy conditions. Atmosphere attenuates the backscatter signal.
Between 0.5 and 4.2	Light to moderate rain conditions. Atmospheric phenomena attenuate the backscatter signal. Most of the attenuation is due to precipitating hydrometeors.
Greater than 4.2	Heavy rain conditions. Backscatter generated by hydrometeors in the atmosphere dominates the scatterometer echo signal. Phenomena that attenuate the backscatter signal are small by comparison.

The value is retrieved using observations of the Advanced Microwave Scanning Radiometer (AMSR).

9.7.2.2 wvc_quality_flag

This flag indicates the quality of wind retrieval within a given wind vector cell. Quality of wind retrieval is based on the number and the quality of the σ_0 measurements within the cell. If the Wind Retrieval Flag (bit 9) is set, then all of wind measurement parameters for the associated wind vector cell contain null values. The significance of each of the bit flags is as follows:

Bit	Definition	Bit Significance
0	Adequate Sigma0 Flag	0 - Adequate good sigma0s available for wind retrieval.
		1 - Not enough good sigma0s available for wind retrieval.
1	Adequate Azimuth Diversity Flag	0 - Good azimuth diversity among sigma0s for wind retrieval.
		1 - Poor azimuth diversity among sigma0s for wind retrieval.
2	Attenuation Method Data Flag	0 - AMSR used to correct sigma0s for atmospheric attenuation.
		1 - Map used to correct sigma0s for atmospheric attenuation.
3 - 4	Available AMSR Attenuation Flag	0 - All of the wind vector cell sigma0s have AMSR attenuation.
		1 - N/A
		2 - Some of the wind vector cell sigma0s have AMSR attenuation.
		3 - None of the wind vector cell sigma0s have AMSR attenuation.

5 - 6	AMSR Weather Condition Flag	0 - Collocated AMSR brightness temperatures indicate clear weather for all sigma0s used in wind retrieval.
		1 - N/A
		2 - Collocated AMSR brightness temperatures indicate light rain for at least one sigma0 used in wind retrieval, no sigma0s are associated with heavy rain.
		3 - Collocated AMSR brightness temperatures indicate heavy rain for at least one sigma0 used in wind retrieval.
7	Coastal Flag	0 - No land mass was detected within the wind vector cell.
		1 - Some portion of the wind vector cell is over land.
8	Ice edge flag.	0 - No ice was detected within the wind vector cell.
		1 - Some portion of the wind vector cell is over ice.
9	Wind Retrieval Flag	0 - Wind retrieval performed for wind vector cell.
		1 - Wind retrieval not performed for wind vector cell.
10	High Wind Speed Flag	0 - Reported wind speed is less than or equal to 30 m/sec.
		1 - Reported wind speed is greater than 30 m/sec.
11	Low Wind Speed Flag	0 - Reported wind speed is greater than or equal to 3 m/sec.
		1 - Reported wind speed is less than 3 m/sec.
12	IMUDH Rain Flag Usable	0 - Rain flag for the wind vector cell is usable.
		1 - Rain flag for the wind vector cell is not usable.
13	IMUDH Rain Flag	0 - IMUDH Rain flag algorithm does not detect rain.
		1 - IMUDH Rain flag algorithm detects rain.
14	Available Data Flag	0 - Inner beam data with SeaWinds view forward and aft and outer beam data with SeaWinds view forward and aft are available.
		1 - Data from at least one of the four possible beam and view combinations are not available.
15	AMSR Rain Indicator Flag	0 - The reported AMSR rain indicator value is usable.
		1 - The reported AMSR rain indicator value is not usable.

9.7.3 Selected Level 2A Definitions

9.7.3.1 sigma0_mode_flag

These bit flags indicate the SeaWinds instrument mode and status at the time the σ_0 measurement was acquired.

The significance of each bit is as follows:

Bit	Definition	Bit Significance
0-1	Calibration/Measurement Pulse Flag	0 - Measurement pulse
		1 - Loop back calibration pulse
		2 - Cold load calibration pulse
		3 - N/A
2	Antenna Beam Flag	0 - Inner antenna beam
		1 - Outer antenna beam
3	Sigma0 Location Flag	0 - Sigma0 cell is forward of spacecraft
		1 - Sigma0 cell is aft of spacecraft
4-5	Current Mode	0 - Wind Observation Mode
		1 - Calibration Mode
		2 - Standby Mode
		3 - Receive Only Mode
6-8	Effective Gate Width - Slice Resolution	0 - 0.0 milliseconds
		1 - 0.1 milliseconds
		2 - 0.2 milliseconds
		3 - 0.3 milliseconds
		4 - 0.4 milliseconds
		5 - 0.5 milliseconds
		6 - 0.6 milliseconds
7 - none - chirp modulation off		
9	Data Acquisition Mode Flag	0 - High resolution mode - slice data
		1 - Low resolution mode - whole pulse data
10	Scatterometer Electronic Subsystem (SES) A/B Flag	0 - SES A
		1 - SES B
11	Antenna Spin Rate	0 - Nominal rate - 18 rpm
		1 - Alternate rate - 19.8 rpm
12	Receive Protect On/Off	0 - Receiver not protected
		1 - Receiver protected
13-15	Slices Per Composite Flag	Spare. Always clear (0).

9.7.3.2 sigma0_qual_flag

These bit flags indicate the quality of the data used to generate the σ_0 measurement. The significance of each bit is as follows:

Bit	Definition	Bit Significance
0	Sigma0 Measurement Usable Flag	0 - Measurement is usable
		1 - Measurement is not usable
1	Low SNR Flag	0 – SNR level is acceptable (SNR \geq TBD)
		1 – SNR level is low (SNR < TBD)
2	Negative Sigma0 Flag	0 - Sigma0 \geq 0
		1 - Sigma0 < 0
3	Sigma0 Out of Range Flag	0 - Sigma0 is in acceptable range
		1 - Sigma0 is outside of acceptable range
4	Pulse Quality Flag	0 - Scatterometer pulse quality is acceptable
		1 - Scatterometer pulse quality is not acceptable
5	Cell Location Flag	0 - Sigma0 cell location algorithm converges
		1 - Sigma0 cell location algorithm does not converge
6	Frequency Shift Flag	0 - Frequency shift is within the range of the x factor table
		1 - Frequency shift lies beyond the range of the x factor table
7	Temperature Range Flag	0 - Spacecraft temperature is within calibration coefficient range
		1 - Spacecraft temperature is beyond calibration coefficient range
8	Attitude Data Flag	0 - An applicable attitude record was found for this sigma0
		1 - No applicable attitude records were found for this sigma0
9	Ephemeris Data Flag	0 - Interpolated ephemeris data are acceptable for this sigma0
		1 - Interpolated ephemeris data are not acceptable for this sigma0
10-11	Best eight slices flag	0 - Slices 2 through 9
		1 - Slices 3 through 10
		2 - Slices 4 through 11
		3 - N/A
12-15	Spare	Always clear (0)

9.7.3.3 surface_flag

These bit flags indicate the effect of surface conditions upon the σ_0 data. The significance of each bit is as follows:

Bit	Definition	Bit Significance
0	Surface land flag	0 - No land is present
		1 - Land is present
1	Surface ice flag determined by map	0 - Map indicates no ice is present
		1 - Map indicates ice is present
2	Surface ice flag determined by AMSR	0 - AMSR indicates no ice is present
		1 - AMSR indicates ice is present
3	AMSR calculated attenuation flag	0 - AMSR data used to calculate attenuation
		1 - AMSR data not used to calculate attenuation
4-6	Spare	Always clear(0)
7-8	Sigma0 rain flag	0 - AMSR observations do not indicate rain conditions
		1 - AMSR observations indicate light to moderate rain conditions
		2 - N/A
		3 - AMSR observations indicate heavy rain conditions
9	Usable AMSR data available flag	0- Usable AMSR data available for this sigma0
		1- Usable AMSR data not available for this sigma0
10	Ice map data available flag	0 - Ice map data available for this sigma0
		1 - Ice map data not available for this sigma0
11	Attenuation map data available flag	0 - Attenuation map data available for this sigma0
		1 - Attenuation map data not available for this sigma0
12-15	Spare	Always clear (0)

9.7.4 Selected Level 1B Definitions

9.7.4.1 cell_kpc_b

A two-dimensional array which contains the first order coefficient of an inverse second order polynomial in the signal to noise ratio. Evaluation of the polynomial yields Kpc for whole pulse σ_0 measurements. Kpc is the normalized standard deviation of σ_0 measure due to statistical fluctuations in the echo signal.

The first dimension index represents the slice resolution mode. For all elements in the cell_kpc_b array, the significance of the first dimension index is as follows:

First Dimension Index	Slice Resolution
0	0.0 msec
1	0.1 msec
2	0.2 msec
3	0.3 msec
4	0.4 msec
5	0.5 msec
6	0.6 msec
7	none - modulation off

The second dimension index represents the scatterometer beam. For all elements in the cell_kpc_b array, the significance of the second dimension index is as follows:

Second Dimension Index	Definition
0	Scatterometer Inner Beam
1	Scatterometer Outer Beam

9.7.4.2 cell_kpc_c

A two-dimensional array which contains the second order coefficient of an inverse second order polynomial in the signal to noise ratio. Evaluation of the polynomial yields K_{pc} for whole pulse σ_o measurements. K_{pc} is the normalized standard deviation of σ_o measure due to statistical fluctuations in the echo signal.

The first dimension index represents the slice resolution mode. For all elements in the cell_kpc_c array, the significance of the first dimension index is as follows:

First Index	Dimension	Slice Resolution
0		0.0 msec
1		0.1 msec
2		0.2 msec
3		0.3 msec
4		0.4 msec
5		0.5 msec
6		0.6 msec
7		none - modulation off

The second dimension index represents the scatterometer beam. For all elements in the cell_kpc_c array, the significance of the second dimension index is as follows:

Second Index	Dimension	Definition
0		Scatterometer Inner Beam
1		Scatterometer Outer Beam

9.7.4.3 frame_err_status

These bit flags indicate potential problems due to instrument error or poor communication with the spacecraft.

The significance of each bit is as follows:

Bit	Definition	Bit Significance
0	Current Error Message Flag	0 - Current error message in telemetry indicates no errors
		1 - Current error message in telemetry indicates errors
1	Equator Crossing Missed	0 - No miss of equator crossing reported
		1 - Miss of equator crossing was reported
2	Misaligned Calibration Pulse Flag	0 - Most recent calibration pulse was where it was expected
		1 - Most recent calibration pulse was not where it was expected
3	Power On Reset	0 - Normal operations, no reset
		1 - Reset event noted
4	CDS Watchdog Timeout Reset	0 - Watchdog resets operating normally
		1 - Watchdog timeout
5	SES Watchdog Timer Event	0 - No watchdog timer event noted
		1 - Watchdog timer event took place
6	Fault Protection Event	0 - Normal operations
		1 - Fault protection event noted
7	Mission Telemetry or Serial Telemetry Error	0 - Normal operations
		1 - Telemetry error noted
8	Missing Spacecraft Time	0 - Normal operations, all spacecraft times available
		1 - Spacecraft time missing event noted
9	Reset Event	0 - No reset event noted
		1 - Reset took place
10	CDS System Reset	0 - Normal operations, no CDS reset
		1 - CDS reset event noted
11	TWTA Malfunction Flag	0 - The active TWTA unit reports no malfunctions
		1 - The active TWTA unit reports a malfunction
12	SES Data Overrun Flag	0 - No SES data overrun detected
		1 - SES data overrun detected
13	SES Data Underrun Flag	0 - No SES data underrun detected
		1 - SES data underrun detected
14	Spare	Always clear (0)

16	A to D Transformer Couple Flag	0 - A to D transformer couple voltage is in range
		1 - A to D transformer couple voltage is out of range
17	Excessive Interpolation of Antenna Position Flag	0 - Fewer than 50 consecutive antenna positions were interpolated
		1 - 50 or more consecutive antenna positions were interpolated
18	Ignored Orbit Step Change Flag	0 - Orbit step change is normal
		1 - Step change denoted, but orbit step is same as previous frame
19	Spontaneous Orbit Step Change Flag	0 - Orbit step change is normal
		1 - Orbit step incremented, but step change was not denoted
20	Inconsistent Resolution Mode Flag	0 - Resolution mode is consistent for both scatterometer beams
		1 - Scatterometer beam resolution modes are inconsistent
21	Unexpected Grid Inhibit Condition	0 - Grid inhibit is in expected state
		1 - Grid inhibit is in unexpected state
22	Unexpected Receive Protect Condition	0 - Receive protect is in expected state
		1 - Receive protect is in unexpected state
23	Attitude Data Flag	0 - An usable attitude record was found for this telemetry frame
		1 - No usable attitude record was found for this telemetry frame
24	Ephemeris Data Flag	0 - Interpolated ephemeris data are acceptable
		1 - Interpolated ephemeris data are unacceptable
25	Telemetry Time Tag Flag	0 - Telemetry packet time tag is acceptable
		1 - Telemetry packet time tag in unreadable or out of range
26	Telemetry Error Message History Flag	0 - Error message history and error count are consistent
		1 - Error message history and error count are inconsistent
27	Valid Operational Mode Flag	0 - Operational mode is valid
		1 - Operational mode in telemetry is not valid
28-31	Spare	Always clear (0)

9.7.4.4 frame_inst_status

These bit flags indicate the status of spacecraft instruments and ground communication over the time span of a single telemetry frame.

The significance of each bit is as follows:

Bit	Definition	Bit Significance
0-1	Current Mode	0 - Wind observation mode
		1 - Calibration mode
		2 - Standby mode
		3 - Receive only mode
2	First Pulse Count in Frame	0 - Pulse A first
		1 - Pulse B first
3	Antenna Spin Rate	0 - Nominal rate - 18 rpm
		1 - Alternate rate - 19.8 rpm
4-6	Slice Resolution Mode - Effective Gate Width	0 - 0.0 milliseconds
		1 - 0.1 milliseconds
		2 - 0.2 milliseconds
		3 - 0.3 milliseconds
		4 - 0.4 milliseconds
		5 - 0.5 milliseconds
		6 - 0.6 milliseconds
		7 - none - modulation off
7	Data Acquisition Mode Flag	0 - High resolution mode - slice data
		1 - Low resolution mode - whole pulse data
8	Cal Pulse Sequence Flag	0 - A calibration pulse sequence begins in this telemetry frame
		1 - No calibration pulse sequence begins in this telemetry frame
9	Scatterometer Electronic Subsystem (SES) A/B Flag	0 - SES A
		1 - SES B
10	SeaWinds Antenna Subsystem (SAS) A/B Flag	0 - SAS A
		1 - SAS B
11	Traveling Wave Tube Amplifier (TWTA) 1/2 Flag	0 - TWTA #1
		1 - TWTA #2
12	Traveling Wave Tube Amplifier (TWTA) Power Flag	0 - TWTA Power On
		1 - TWTA Power Off
13	Grid Enable/Disable Flag	0 - Grid normal for RF transmission

		1 - Grid disable, no RF transmission
14	Receive Protect On/Normal	0 - Receive protect normal
		1 - Receive protect on
15	TWT Trip Override	0 - TWT trip override off
		1 - TWT trip override on
16	TWT Body Overcurrent Trip Control	0 - TWT body overcurrent trip enabled
		1 - TWT body overcurrent trip disabled
17	Receive Protect On/Off	0 - Receiver not protected
		1 - Receiver protected
18	Instrument Mode Change	0 - Instrument operations mode did not change
		1 - Instrument operations mode did change
19	Soft Reset Commanded	0 - No flight software soft reset commanded
		1 - Flight software soft reset commanded
20	Relay Set/Reset Started	0 - No change reported
		1 - Change from last packet
21	Internal PRF Clock	0 - Internal PRF clock measure received from SES
		1 - CDS hardware generated PRF clock
22	Hard Reset Commanded	0 - No hard reset commanded
		1 - Hard reset commanded
23	TWTA Monitor Enable/Disable	0 - No change in state of TWTA monitor
		1 - Change in state of TWTA monitor
24	SES Parameter Table Change	0 - No change in the SES parameter tables
		1 - Change in the SES parameter tables
25	Range Gate Table Change	0 - No change in the Range Gate tables
		1 - Change in the Range Gate tables
26	Doppler Table Change	0 - No change in the Doppler tables
		1 - Change in the Doppler tables
27	Serial Telemetry Table Change	0 - No change in the Serial Telemetry tables
		1 - Change in the Serial Telemetry tables
28	Mission Telemetry Table Change	0 - No change in the Mission Telemetry tables
		1 - Change in the Mission Telemetry tables
29	Resolution Mode Change	0 - No change in the slice resolution mode
		1 - Change in the slice resolution mode
30-31	Spare	Always clear (0)

9.7.4.5 frame_qual_flag

These bit flags indicate the character and the quality of the data acquired within a particular telemetry frame.

The significance of each bit is as follows:

Bit	Definition	Bit Significance
0-1	Frame filler flag	0 - No filler in telemetry frame
		1 - Filler only in packet 2
		2 - Filler only in packet 3
		3 - Filler in both packets 2 and 3
2-3	Spare	Always clear (0)
4	Data quality flag	0 - Good data found in telemetry frame
		1 - Questionable or bad data found in telemetry frame
5-15	Spare	Always clear (0)

9.7.4.6 sigma0_mode_flag

These bit flags indicate the SeaWinds instrument mode and status at the time the σ_0 measurement was acquired.

The significance of each bit is as follows:

Bit	Definition	Bit Significance
0-1	Calibration/Measurement Pulse Flag	0 - Measurement pulse
		1 - Loop back calibration pulse
		2 - Cold load calibration pulse
		3 - N/A
2	Antenna Beam Flag	0 - Inner antenna beam
		1 - Outer antenna beam
3	Sigma0 Location Flag	0 - Sigma0 cell is forward of spacecraft
		1 - Sigma0 cell is aft of spacecraft
4-5	Current Mode	0 - Wind Observation Mode
		1 - Calibration Mode
		2 - Standby Mode
		3 - Receive Only Mode
6-8	Effective Gate Width - Slice Resolution	0 - 0.0 milliseconds
		1 - 0.1 milliseconds
		2 - 0.2 milliseconds
		3 - 0.3 milliseconds
		4 - 0.4 milliseconds
		5 - 0.5 milliseconds
		6 - 0.6 milliseconds
		7 - none - chirp modulation off
9	Data Acquisition Mode Flag	0 - High resolution mode - slice data
		1 - Low resolution mode - whole pulse data
10	Scatterometer Electronic Subsystem (SES) A/B Flag	0 - SES A
		1 - SES B
11	Antenna Spin Rate	0 - Nominal rate - 18 rpm
		1 - Alternate rate - 19.8 rpm
12	Receive Protect On/Off	0 - Receiver not protected
		1 - Receiver protected
13-15	Spare	Always clear (0)

9.7.4.7 sigma0_qual_flag

These bit flags indicate the quality of the data that generate the σ_0 measurement.

The significance of each bit is as follows:

Bit	Definition	Bit Significance
0	Sigma0 Measurement Usable Flag	0 - Measurement is usable
		1 - Measurement is not usable
1	Low SNR Flag	0 - SNR level is acceptable
		1 - SNR level is low
2	Negative Sigma0 Flag	0 - $\text{Sigma0} \geq 0$
		1 - $\text{Sigma0} < 0$
3	Sigma0 Out of Range Flag	0 - Sigma0 is in acceptable range
		1 - Sigma0 is outside of acceptable range
4	Pulse Quality Flag	0 - Scatterometer pulse quality is acceptable
		1 - Scatterometer pulse quality is not acceptable
5	Cell Location Flag	0 - Sigma0 cell location algorithm converges
		1 - Sigma0 cell location algorithm does not converge
6	Frequency Shift Flag	0 - Frequency shift is within the range of the x factor table
		1 - Frequency shift lies beyond the range of the x factor table
7	Temperature Range Flag	0 - Spacecraft temperature is within calibration coefficient range
		1 - Spacecraft temperature is beyond calibration coefficient range
8	Attitude Data Flag	0 - An usable attitude record was found for this sigma0
		1 - No usable attitude records were found for this sigma0
9	Ephemeris Data Flag	0 - Interpolated ephemeris data are acceptable for this sigma0
		1 - Interpolated ephemeris data are not acceptable for this sigma0
10-11	Best Eight Slices Flag	0 - Slices 2 through 9
		1 - Slices 3 through 10
		2 - Slices 4 through 11
		3 - N/A
12-15	Spare	Always clear (0)

9.7.4.8 slice_kpc_b

A two-dimensional array which contains the first order coefficient of an inverse second order polynomial in the signal to noise ratio. Evaluation of the polynomial yields Kpc for slice σ_o measurements. Kpc is the normalized standard deviation of σ_o measure due to statistical fluctuations in the echo signal.

The first dimension index represents the slice resolution mode. For all elements in the slice_kpc_b array, the significance of the first dimension index is as follows:

First Index	Dimension	Slice Resolution
0		0.0 msec
1		0.1 msec
2		0.2 msec
3		0.3 msec
4		0.4 msec
5		0.5 msec
6		0.6 msec
7		none - modulation off

The second dimension index represents the scatterometer beam. For all elements in the slice_kpc_b array, the significance of the second dimension index is as follows:

Second Index	Dimension	Definition
0		Scatterometer Inner Beam
1		Scatterometer Outer Beam

9.7.4.9 slice_kpc_c

A two-dimensional array which contains the second order coefficient of an inverse second order polynomial in the signal to noise ratio. Evaluation of the polynomial yields Kpc for slice σ_o measurements. Kpc is the normalized standard deviation of σ_o measure due to statistical fluctuations in the echo signal.

The first dimension index represents the slice resolution mode. For all elements in the slice_kpc_c array, the significance of the first dimension index is as follows:

First Index	Dimension	Slice Resolution
0		0.0 msec
1		0.1 msec
2		0.2 msec
3		0.3 msec
4		0.4 msec
5		0.5 msec
6		0.6 msec
7		none - modulation off

The second dimension index represents the scatterometer beam. For all elements in the slice_kpc_c array, the significance of the second dimension index is as follows:

Second Index	Dimension	Definition
0		Scatterometer Inner Beam
1		Scatterometer Outer Beam

9.7.4.10 slice_qual_flag

These bit flags indicate the quality of the data, which generate the σ_0 measurements for each of the slices of the scatterometer pulse.

The significance of each bit is as follows:

Bit	Definition	Bit Significance
0	Peak Gain Flag for slice 1	0 - Gain exceeds peak gain threshold
		1 - Gain does not exceed peak gain threshold
1	Negative Sigma0 Flag for slice 1	0 - $\text{Sigma}0 \geq 0$
		1 - $\text{Sigma}0 < 0$
2	Low SNR Flag for slice 1	0 - SNR level is acceptable ($\text{SNR} \geq \text{TBD}$)
		1 - SNR level is low ($\text{SNR} < \text{TBD}$)
3	Center Location Flag for slice 1	0 - Slice center located
		1 - Slice center not located
4	Peak Gain Flag for slice 2	0 - Gain exceeds peak gain threshold
		1 - Gain does not exceed peak gain threshold
5	Negative Sigma0 Flag for slice 2	0 - $\text{Sigma}0 \geq 0$
		1 - $\text{Sigma}0 < 0$
6	Low SNR Flag for slice 2	0 - SNR level is acceptable ($\text{SNR} \geq \text{TBD}$)
		1 - SNR level is low ($\text{SNR} < \text{TBD}$)
7	Center Location Flag for slice 2	0 - Slice center located
		1 - Slice center not located
8	Peak Gain Flag for slice 3	0 - Gain exceeds peak gain threshold
		1 - Gain does not exceed peak gain threshold
9	Negative Sigma0 Flag for slice 3	0 - $\text{Sigma}0 \geq 0$
		1 - $\text{Sigma}0 < 0$
10	Low SNR Flag for slice 3	0 - SNR level is acceptable ($\text{SNR} \geq \text{TBD}$)
		1 - SNR level is low ($\text{SNR} < \text{TBD}$)
11	Center Location Flag for slice 3	0 - Slice center located
		1 - Slice center not located
12	Peak Gain Flag for slice 4	0 - Gain exceeds peak gain threshold
		1 - Gain does not exceed peak gain threshold
13	Negative Sigma0 Flag for slice 4	0 - $\text{Sigma}0 \geq 0$
		1 - $\text{Sigma}0 < 0$
14	Low SNR Flag for slice 4	0 - SNR level is acceptable ($\text{SNR} \geq \text{TBD}$)
		1 - SNR level is low ($\text{SNR} < \text{TBD}$)
15	Center Location Flag for slice 4	0 - Slice center located

		1 - Slice center not located
16	Peak Gain Flag for slice 5	0 - Gain exceeds peak gain threshold
		1 - Gain does not exceed peak gain threshold
17	Negative Sigma0 Flag for slice 5	0 - $\text{Sigma}0 \geq 0$
		1 - $\text{Sigma}0 < 0$
18	Low SNR Flag for slice 5	0 - SNR level is acceptable ($\text{SNR} \geq \text{TBD}$)
		1 - SNR level is low ($\text{SNR} < \text{TBD}$)
19	Center Location Flag for slice 5	0 - Slice center located
		1 - Slice center not located
20	Peak Gain Flag for slice 6	0 - Gain exceeds peak gain threshold
		1 - Gain does not exceed peak gain threshold
21	Negative Sigma0 Flag for slice 6	0 - $\text{Sigma}0 \geq 0$
		1 - $\text{Sigma}0 < 0$
22	Low SNR Flag for slice 6	0 - SNR level is acceptable ($\text{SNR} \geq \text{TBD}$)
		1 - SNR level is low ($\text{SNR} < \text{TBD}$)
23	Center Location Flag for slice 6	0 - Slice center located
		1 - Slice center not located
24	Peak Gain Flag for slice 7	0 - Gain exceeds peak gain threshold
		1 - Gain does not exceed peak gain threshold
25	Negative Sigma0 Flag for slice 7	0 - $\text{Sigma}0 \geq 0$
		1 - $\text{Sigma}0 < 0$
26	Low SNR Flag for slice 7	0 - SNR level is acceptable ($\text{SNR} \geq \text{TBD}$)
		1 - SNR level is low ($\text{SNR} < \text{TBD}$)
27	Center Location Flag for slice 7	0 - Slice center located
		1 - Slice center not located
28	Peak Gain Flag for slice 8	0 - Gain exceeds peak gain threshold
		1 - Gain does not exceed peak gain threshold
29	Negative Sigma0 Flag for slice 8	0 - $\text{Sigma}0 \geq 0$
		1 - $\text{Sigma}0 < 0$
30	Low SNR Flag for slice 8	0 - SNR level is acceptable ($\text{SNR} \geq \text{TBD}$)
		1 - SNR level is low ($\text{SNR} < \text{TBD}$)
31	Center Location Flag for slice 8	0 - Slice center located
		1 - Slice center not located